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AN INVESTIGATION OF THE CONSOLIDATION OF SOILS UNDER CONDITIONS OF TIME-DEPENDENT LOADING AND VARYING PERMEABILITY

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AN INVESTIGATION OF THE CONSOLIDATION OF SOILS UNDER CONDITIONS OF TIME-DEPENDENT LOADING AND VARYING PERMEABILITY

by

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A Thesis Submitted to the Faculty
of the Department of Civil Engineering
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Approved:

____
Advisor

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FORWORD

The author wishes to express his sincere appreciation to Assistant Professor Robert L. Schiffman, for his assistance in selection of the topic, and his guidance and constructive advice in setting up and conducting the experimental phases of the research conducted. His timely suggestions and explanations of research objectives and requirements have been of inestimable value in this work.

In addition, the author wishes to acknowledge with gratitude, the innumerable helpful hints and practical suggestions offered by Associate Professor Stanley V. Best, without whose excellent class-room instruction the understanding of the subject matter would have been many times more difficult.

ABSTRACT

The Terzaghi Theory of Consolidation does not consider the time-dependent loading conditions, encountered in ordinary construction practice, except in a graphical approximation. The development of a rigorous mathematical solution to this problem by Schiffman requires simplifying assumptions relative to the permeability and consolidation characteristics of the soil in order that the general differential equation for consolidation under such loading may be linearized.

The investigation of the validity of these assumptions for the case of one-dimensional flow was conducted, utilizing both standard lever-arm and bellows type consolidation equipment. The assembly and use of a constant-head permeameter to measure flow volume through a consolidating soil mass provided, for the first time, an opportunity to correlate instantaneous and average values of the coefficient of permeability, with the porosity existant at the time of reading. The wide variance in instantaneous values dictated the use of finite incremental average values. By limiting the time increment to 15 minutes, it was found that analysis of data was considerably improved.

Four consolidation tests were conducted, using instantaneous standard incremental loading, time-dependent loading and small incremental loading. A proposed fifth test

using small incremental loading was cancelled due to failure of a metal casting in the equipment under 16TSF loading. A pure Kaolin clay was tested in order to limit the number of variables entering into the problem. It was considered that the use of undisturbed natural soil samples would introduce intangible factors which would seriously interfere with the objectives of this pilot study.

Analysis of test data shows that, for construction-type (i.e. time-dependent loading), the assumption of linear variation of permeability with porosity, utilized by Schiffman in his solution of the general differential equation of consolidation, is valid, but only for small load increments. The linearity of this relationship does not appear to hold under conditions of large absolute loads applied over a short time period. It is hypothisized that the apparent exponential relationship is the result of the shearing of adsorbed water from the clay particle during an intense structural densification under such loading. Further study of this problem was strongly recommended.

The approximation technique utilized by Schiffman, in the solution of the variable permeability case, was found to be limited in accuracy only by the time-increment used by the investigator. A wide variance in average values of the coefficient of permeability was found to exist under all conditions of loading, which factor requires almost constant

attendance if the average value is to approach the instantaneous value.

No conclusion was drawn relative to the consolidation-permeability-time relationship under time dependent loading, since fitting procedures for the test curves were not established during this investigation.

PART 1.

INTRODUCTION

A. Objective

The furnishing of a reasonably accurate engineering estimate of the settlement to be encountered in the founding of man's structures on soil strata which have been subjected to the vagaries and assaults of natural forces for millenia of time, has been one of the most important contributions of the field of soil mechanics to the Engineering Profession. The complexity of the solution to this problem cannot be overstated, since both interdependent and non-dependent, linear and non-linear, variables are encountered throughout any analysis of the settlement characteristics of Engineering Soils.

It is the current practice of Soil Mechanics and Foundation Engineers to compute total settlement and the time-rate of settlement of loaded compressible strata in accordance with the mathematical analysis developed by Dr. Karl Terzaghi in his theory of consolidation. Although rigidly correct for the assumptions used by Dr. Terzaghi, the use of the Terzaghi theory does not always render satisfactory results, since the simplifying assumptions of the theory cannot usually be found in the field. Among the assumptions used by Dr. Terzaghi is the concept that loads are applied to the soil instantaneously without changing its

permeability characteristics. Although several others of the basic assumptions of the theory of consolidation are subject to critical revue, an extension to the Terzaghi theory as developed by Assistant Professor R.L. Schiffman of the Civil Engineering Department, Rensselaer Polytechnic Institute, proposes a solution to the settlement problem which considers the loading to be time-dependent and the permeability to be variable. Since this analysis closely approximates field conditions, it is considered that a more accurate appraisal of the action of soils under loading may be gained by its use, vice the original Terzaghi theory.

With certain simplifying assumptions, the Schiffman concepts can be used to predict the total settlement and the time-rate of settlement of compressible strata under time-dependent loading, within the limits of mathematical accuracy and the validity of the simplifying assumptions. The validity of these assumptions is the standard against which the application of Professor Shiffman's solution must be measured, if the solution is to be considered a useful contribution to the practice of Civil Engineering.

It is the specific objective of this thesis to conduct a series of tests designed to investigate the time effects of continuously varying loading on the consolidation of soils and the variation of soil permeability with pore

pressures induced by such loading.

The general objective of these investigations is to contribute to a more thorough and basic understanding of the action of compressible soils under loading, with commensurately improving accuracy in the prediction of settlements.

I

B. Historical Review

The accurate prediction of the settlement characteristics of compressible soil strata under loading has been a major topic for research and discussion for several decades. The statement of Collingwood (1) in 1891 that sound undisturbed earth "should be penetrated to a sufficient depth to insure that it is not underlain by semi-fluid or compressible material, which may in time yield and cause trouble and danger..." while qualitative in nature, nevertheless indicates an awareness by practicing Civil Engineers of that era, of the basic cause of the settlement phenomenon.

Although the scientific approach to the understanding of soil action had been in the process of development by such pioneers as Wollny 1879-98 (2), Schlicter 1897 (3), King 1899 (4), et al it is to be noted that their work, while contributory to the broad base of fundamental soil knowledge, was primarily directed toward the agricultural uses of soils. Thus the use of engineering judgement and experience, and emperically derived formulae remained the tools of the Foundation Engineer until well into the second decade of the present century.

With the publication in 1925 of his "Theory of Consolidation", Dr. Karl Terzaghi (5) provided a major

contribution to the scientific evaluation of one of the Foundation Engineers most perplexing problems - the prediction of settlements to be expected after loading a compressible soil. Using fundamental physical laws and simplifying assumptions, Dr. Terzaghi developed a mathematical treatment of the complex functional inter-relationships of various soil properties which by thermodynamic analogue yielded a differential equation solvable by use of Fourier Series. His theory, based in part on instantaneously applied loading and constant permeability, for the first time provided a quantitative, albeit not completely accurate, measure of the consolidation of compressible soil strata under loading. By his solution of the Consolidation problem Dr. Terzaghi, in the words of Professor F.P.Tschebotarioff,"became the founder of the new science of soil mechanics" (6). In 1941 Professor E.J. Kilkawley (7) brought together the fundamental concepts underlying Dr. Terzaghi's work, and presented a solution of the differential equation under conditions of loading and drainage encountered in the field.

It is obvious that the assumption of instant-antaneously applied loading, while achievable in the laboratory, cannot be duplicated in the erection of a structure. In an effort to account for this incongruity in computing time-rates and total settlement, Dr. Terzaghi advanced an approximate graphical method which after

extensions by Professor Gilbuy and Professor Taylor (8) has been accepted as the closest available approach to field loading conditions. The recent work of Professor Schiffman (9) in developing a rigorous mathematical analysis of the consolidation process, as it is affected by the time-rate of loading, permits an analytical evaluation of the settlement to be encountered without recourse to graphical approximations. It is the purpose of this thesis to investigate the validity of Professor Schiffman's assumptions in extending Dr. Terzashi's work.

PART 11.

THEORY

A. The Consolidation Process

The compression of soils under externally applied loads, either natural or man-made, is the basic cause of settlement of structures. This compression is intimately associated with the pore spaces,(ie. intergranular voids) of the soil structure, and the escape of ground water, therefrom. Since both water and the soil grains are considered incompressible, the only way that the height of a soil mass can be reduced, in the vertical plane, is by the escape of the pore water from the soil structure with a concurrent, densifying, structural rearrangement of the soil grains. Thus it is seen that the rate of compression of a soil is a function of the rate of escape of pore water.

With the application of load to a saturated perious soil mass such as clean sand, the escape of pore water is almost instantaneous, since the perviousness of the soil places no obstacle to free passage of water. On the other hand, if the loaded soil is a saturated clay, the escape of the pore water requires considerable time for completion. At the instant after load application, before any pore water has escaped, the soil structure cannot support any of the applied load, since it is in equilibrium, and any change in this condition requires rearrangement (ie.compression). It follows

that the load is supported, temporarily by the pore water, which must incur an increase in pressure to perform this task. This increase in pore water pressure is termed "hydrostatic excess pressure". Under conditions of boundary drainage, the hydrostatic excess pressure is subsequently relieved by the escape of pore water. This pressure relief by boundary drainage, requires transfer of stress from the escaping pore-water to the grains of the soil structure, which reacts to the induced forces of loading by a reduction in volume equivilent to the volume of escaping pore water, thus permitting additional intergranular contact to absorb the transferred stresses. In this manner, the stresses due to loading slowly pass from hydrostatic excess pressures to intergranular or effective pressures, with full stress assumption by the soil structure, upon complete dissipation of the hydrostatic excess. This adjustment process whether it be relatively fast, as in sands, or very slow, as in impervious clays, is termed "consolidation". In its simplest form the consolidation process is reducible at any instant of time to the equation;

$$\underline{p = u + \bar{\sigma}}$$

where p is the compressive stress due to the applied load
u is the hydrostatic excess pressure
$\bar{\sigma}$ is the effective pressure

For the limiting conditions of (1) no dissipation of hydrostatic excess and (2) complete dissipation of hydrostatic

excess, the equation reduces to

(1) $\underline{p = u}$

(2) $\underline{p = \bar{\sigma}}$

B. <u>The Terzaghi Theory of Consolidation</u>

The analysis of the consolidation process developed by Terzaghi is based on the following assumptions:

1. Homogeneous soil mass
2. Complete saturation
3. Negligible compression of soil grains and water
4. Action of infinitessimal masses no different from that of larger, representative masses
5. One-dimensional compression
6. One-dimensional flow
7. Darcy's Law is strictly valid
8. Constant values for certain soil properties which actually vary with pressure
9. Void ratio varies linearly with applied pressures

With the exception of the ninth listed assumption only minor inaccuracies are considered to stem from these assumptions. The linear relationship between void-ratio and pressure introduces serious discreponcies which limit the valadity of the solution. However, the solution would be well-nigh impossibly complex under any other type of functional variance.

Figure 1 illustrates the consolidation process under consideration. A clay layer of thickness 2H, between two pervious sand layers is stressed by an applied unit load p. Boundary Drainage permits dissipation of the hydrostatic

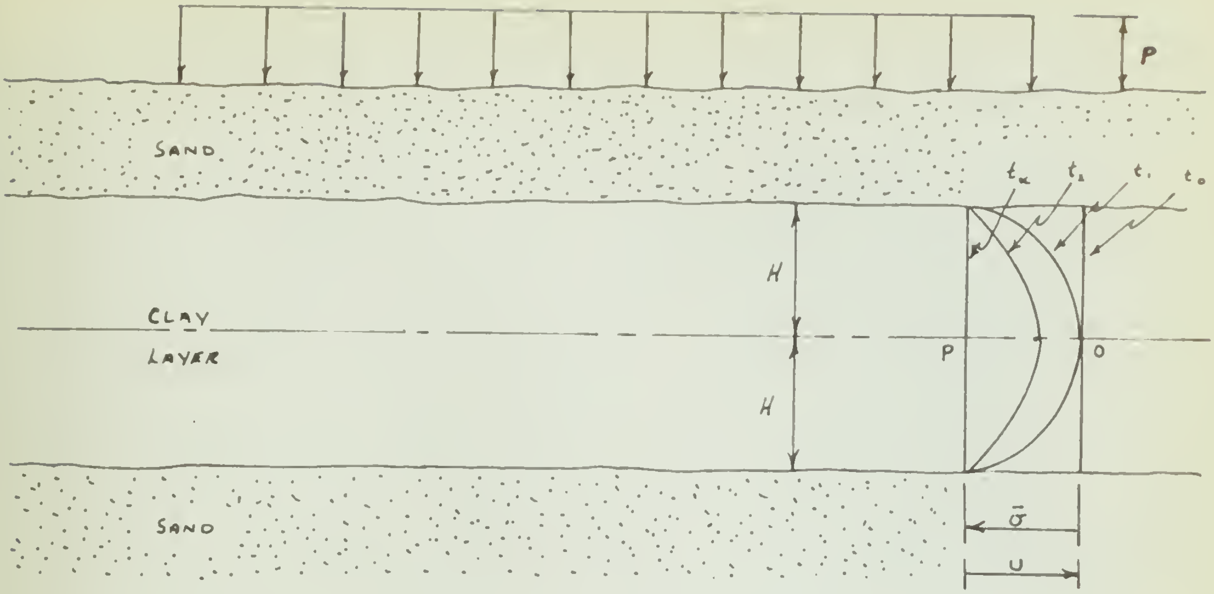


FIG. 1 - THE CONSOLIDATION PROCESS

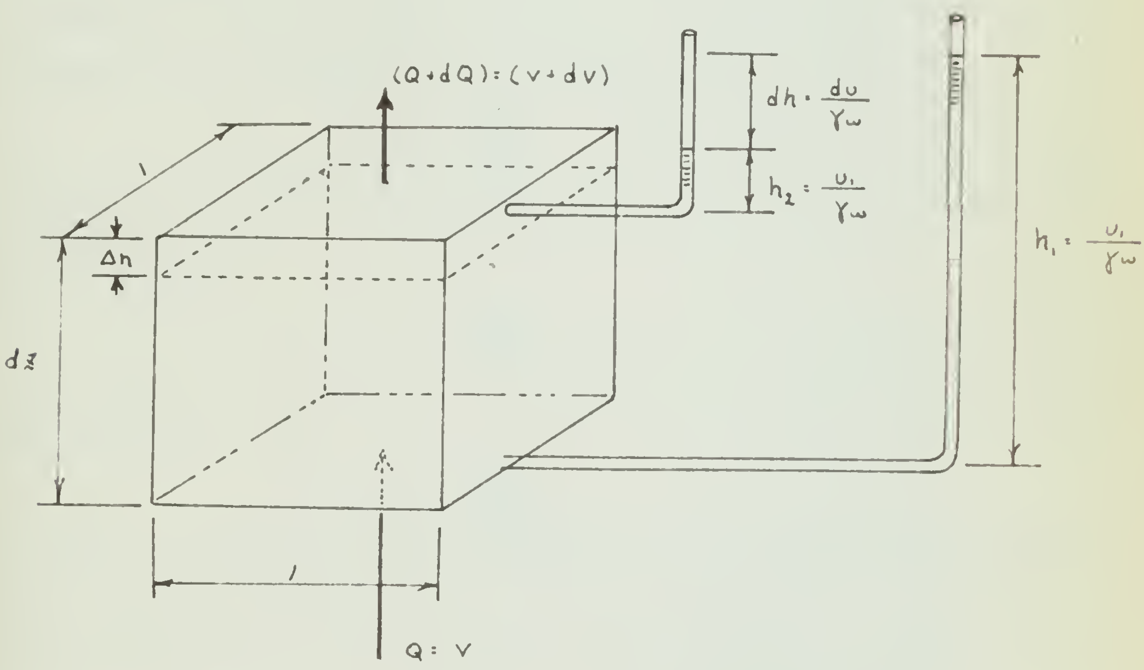


FIG. 2 - DIFFERENTIAL PRISM OF SOIL USED IN ANALYSIS OF CONSOLIDATION PROCESS

excess pressures induced in the pore water. As dissipation progresses the effective pressure $\bar{\sigma}$ increases from 0 at time t_0 to $\bar{p}$ at time t_∞ when the process is completed. At intermediate times t_1, t_2 ..etc. the consolidation process is shown to be more advanced toward the surface and less advanced at the center of the stratum. Consider, now, a differential prism of soil from the upper half of the clay layer, with cross sectional area of 1 and height dz as shown in Figure 2. The piezometer tubes are considered to accurately measure pore-water pressure at top and bottom boundaries. Since pore water is escaping through the upper boundary, a drop in head is occuring in the direction of flow. This drop in head, dh is related to the dissipation of hydrostatic excess du by

$$dh = \frac{du}{\gamma_w} \qquad \gamma_w = \text{unit wt of water}$$

the hydraulic gradient, i, is defined as the drop of head over a given distance.

$$i = \frac{dh}{dz}$$

By substitution

$$i = \frac{du}{\gamma_w dz}$$

Darcy's Law for flow of water through soil masses states that the rate of flow is proportional to the hydraulic gradient

$$v = ki \qquad k = \text{coefficient of permeability}$$

$$v = \text{flow velocity}$$

Again by substitution

$$V = \frac{k}{\gamma_w}\frac{du}{dz}$$

By differentiation, the change in flow velocity over distance dz during a given time interval dt equals

$$\frac{\partial v}{\partial z} = -\frac{K}{\gamma_w}\frac{\partial^2 u}{\partial z^2}$$

Since Darcy's Law can also be stated in the form:

$$V = \frac{Q}{At}$$ where Q = discharge

A = Cross Sectional Area

t = time

it follows that, in time interval dt with A = 1, V = Q (i.e.: that the flow velocity represents the amount of water entering the base of the prism sketched in figure 2) then, the increment of velocity gained over the height of the prism, dz, must equal the increase in discharge through the top of the prism, ie. $dv = dQ$

Any increase in discharge from a fully saturated soil must result in a decrease in pore volume. This Porsity change Δn can be expressed as:

$$\Delta n = \frac{\Delta e}{1+e}$$ where e = void ratio

and since the coefficient of compressibility $a_v = \frac{\Delta e}{\Delta P}$

$$\Delta n = \frac{a_v \Delta P}{1+e}$$

When the change in pore volume Δn is completed, the pressure, p, equals the effective pressure carried by the soil grains, $\bar{\sigma}$, and the preceding equation can be expressed as

$$\frac{\partial n}{\partial t} = - \frac{\partial \bar{\sigma}}{\partial t} \frac{a_v}{1+e}$$

Any increase in $\bar{\sigma}$ under constant unit load P during time interval dt must equal the decrease in Hydrostatic Excess Pressure, U, during the same time period.

$$\therefore \quad \frac{\partial u}{\partial t} = - \frac{\partial \bar{\sigma}}{\partial t} \qquad\qquad \frac{\partial n}{\partial t} = \frac{\partial u}{\partial t} \frac{a_v}{1+e}$$

now since

$$\frac{\partial v}{\partial z} = - \frac{k}{\gamma_w} \frac{\partial^2 u}{\partial z^2} \qquad\qquad \frac{\partial v}{\partial z} = - \frac{\partial n}{\partial t}$$

and

$$\frac{\partial n}{\partial t} = \frac{\partial u}{\partial t} \frac{a_v}{1+e}$$

it follows that:

$$\frac{\partial u}{\partial t} \frac{a_v}{1+e} = \frac{k \, \partial^2 u}{\gamma_w \, \partial z^2}$$

or $$\frac{\partial u}{\partial t} = C_v \frac{\partial^2 u}{\partial z^2}$$ The fundamential differential equation of consolidation

where $$Cv = \frac{k(i + e)}{a_v \gamma_w}$$ = Coefficient of Consolidation

The solution of the fundamental differential equation by Fourier Series, for the boundary conditions as shown in

Figure 1, is as follows

$$u = p\,\frac{4}{\pi}\sum_{n=0}^{n=\infty}\frac{1}{2n+1}\left[\sin\frac{(2n+1)\pi z}{2H}\right]e^{-\frac{(2n+1)^2\pi^2 T}{4}}$$

Where a dimensionless Time factor $T = \frac{t}{H}$

With Cv = Coefficient of Consolidation

t = time for Hydrostatic Excess to decrease to U

H = Longest Drainage Path for water flow

By plotting values of U for various values of $\frac{z}{H}$ and T, the family of curves shown in Figure 3 eliminates the tedious solution of the consolidation equation and permits the use of Figure 4 as a practical method of arriving at a prediction of settlement under loading. Since the ultimate settlement

$$\rho_v = \frac{\Sigma H}{1+e}\, a_v\, \Delta P$$

then the settlement at any time interval equals

$$\rho = \frac{u_{avg}}{u_i}\,\rho_v$$

Where Uavg = Average Hydrostatic Excess

Ui = Initial Hydrostatic Excess

However, among the factors ignored by the Terzaghi solution is the gradual, rather than instantaneously, applied loading encountered in the construction process. A graphical approximation, based on the premise that, at the end of construction, the settlement is the same as that which would have resulted in half the time, if the entire load had been

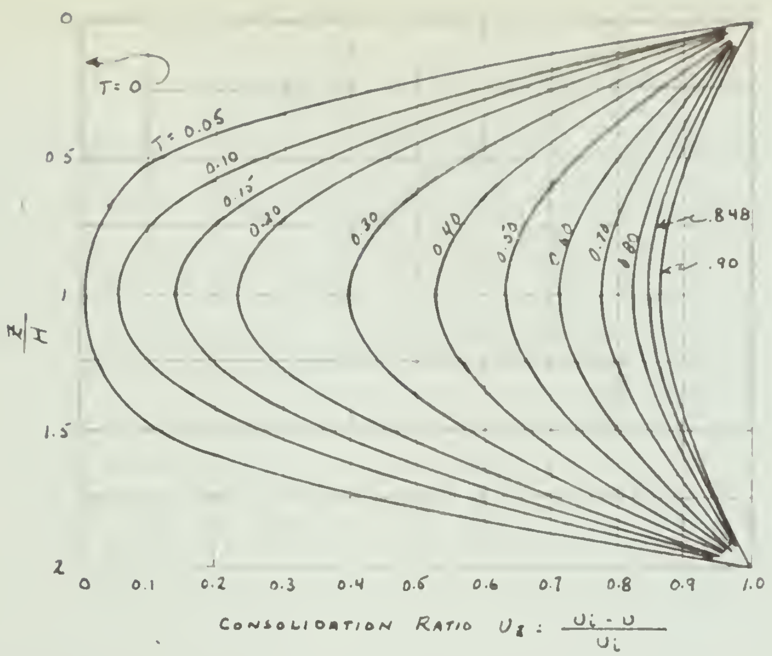


FIG 3 - CONSOLIDATION AS A FUNCTION OF DEPTH AND TIME FACTOR

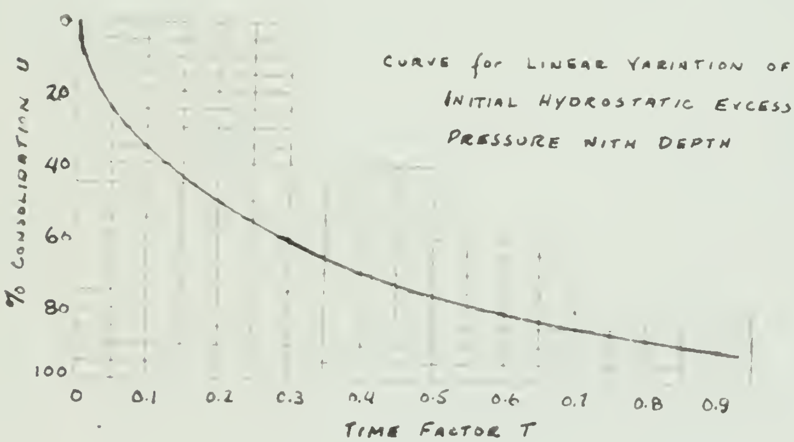


FIG 4 - CONSOLIDATION CURVE — ACCORDING TO THE TERZAGHI THEORY

applied throughout, was first proposed by Terzaghi and Gilboy. Taylor extended it to provide for predicting settlements during the loading period, by assuming that at any specified percentage of the loading period, the load acting equals this percentage of the total load; and at this time, the settlement equals the settlement at one-half the time in question from the curve of time vs. settlement for instantaneous loading. Figure 5 illustrates this correction.

The solution of the fundamental differential equation which by tabulation gives the curves of Figures 3 and 4, was based upon homogeneous boundary conditions, i.e., pressures at the top and bottom of the sample are equal. The use of a constant head permeameter imposes different boundary conditions than these, in that the applied load is resisted by the constant pressure-head of the Permeameter. The following solution to this problem has been developed by Professor Schiffman and graphical values for the loads applied are presented as Figures 6, 7a and 7b:

$$\frac{\bar{u}}{u_0} = \frac{u_1}{2u_0}\left[1 - \frac{\bar{\bar{u}}}{u_0}\right] - \frac{\bar{\bar{u}}}{u_0}$$

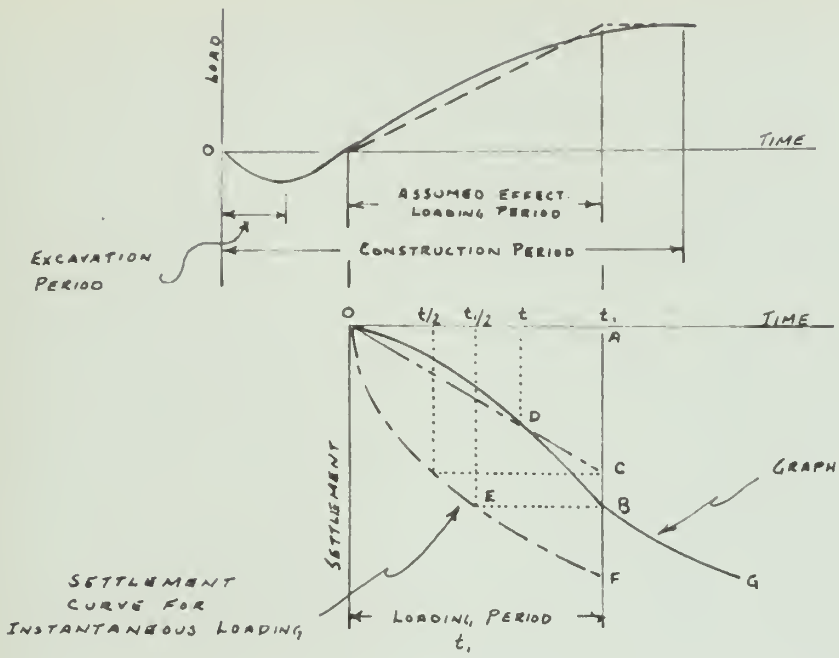
where $\frac{\bar{u}}{u_0}$ = 1 - % Consolidation

u_1 = Pressure due to Permeameter Head

u_0 = Pressure due to applied load increment

$\bar{u}$ = Average Hydrostatic Escess Pressure

$\frac{\bar{\bar{u}}}{u_0}$ = % Consolidation with Homogeneous Boundary Pressures



PROCEDURE

1. SETTLEMENT AT TIME t_1 = SETTLEMENT AT TIME $t_1/2$ ON INSTANTANEOUS CURVE (i.e. SETTLEMENT : AB)
2. LOAD ACTING AT TIME t : t/t_1 × TOTAL LOAD
3. MULTIPLY SETTLEMENT AC FOR TIME t by t/t_1 to FIND SETTLEMENT VALUE FOR APPROXIMATION TO ACTUAL SETTLEMENT
4. PERFORM 3. GRAPHICALLY AS FOLLOWS:
   a. DIAGONAL OC INTERSECTS TIME t AT $D = t/t_1 \times AC$
   b. D = POINT ON APPROXIMATION CURVE
   c. OBTAIN COMPLETE CURVE BY REPETITION for VARIOUS TIMES
5. BEYOND B, APPROXIMATION CURVE IS OFFSET HORIZONTALLY FROM THE INSTANTANEOUS CURVE BY 1/2 THE LOADING PERIOD (i.e. BE = GF)

FIG. 5 - GRAPHICAL APPROXIMATION OF THE SETTLEMENT CURVE DURING THE CONSTRUCTION LOADING PERIOD (AFTER TAYLOR) (8)

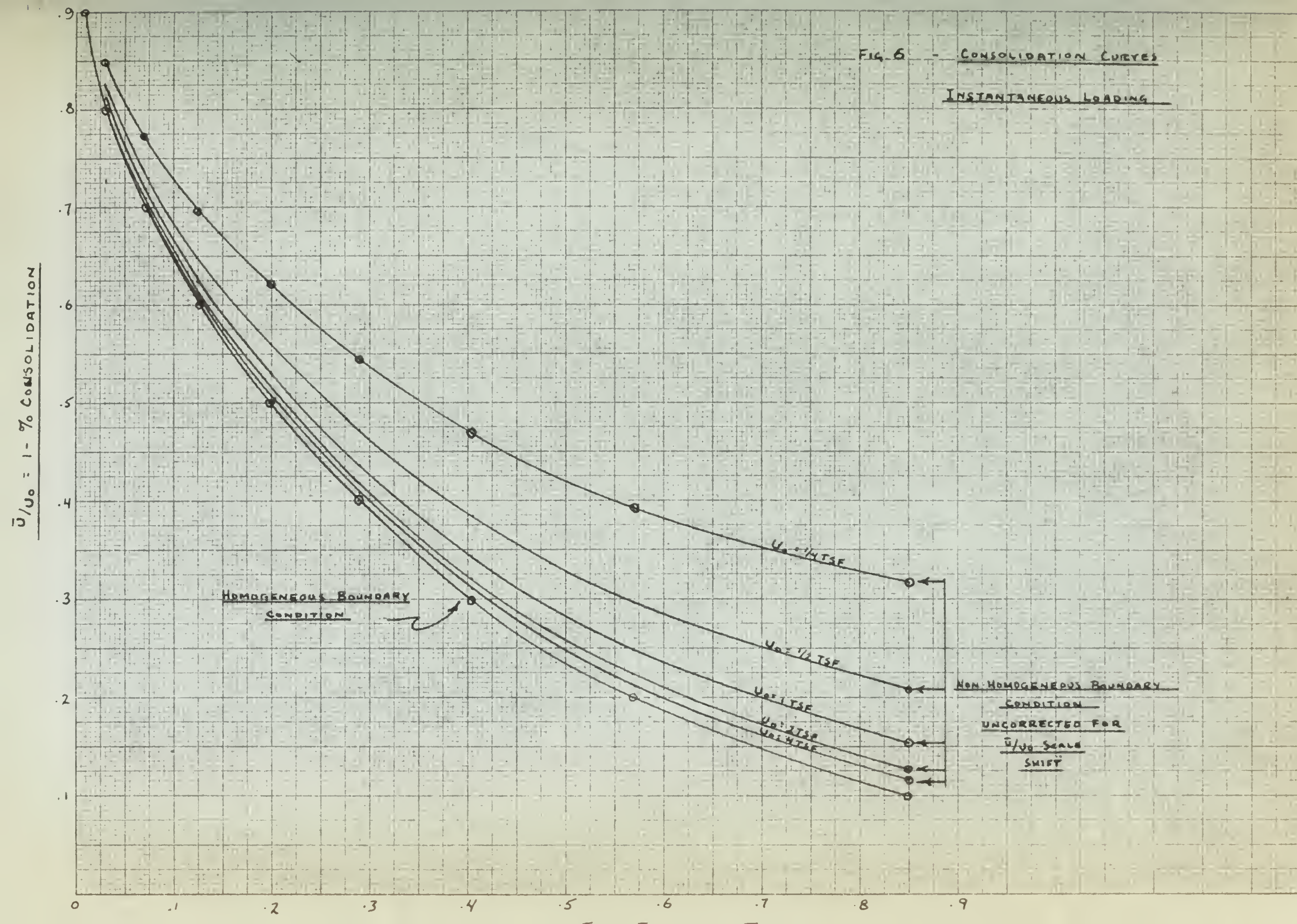


FIG. 6 - CONSOLIDATION CURVES

INSTANTANEOUS LOADING

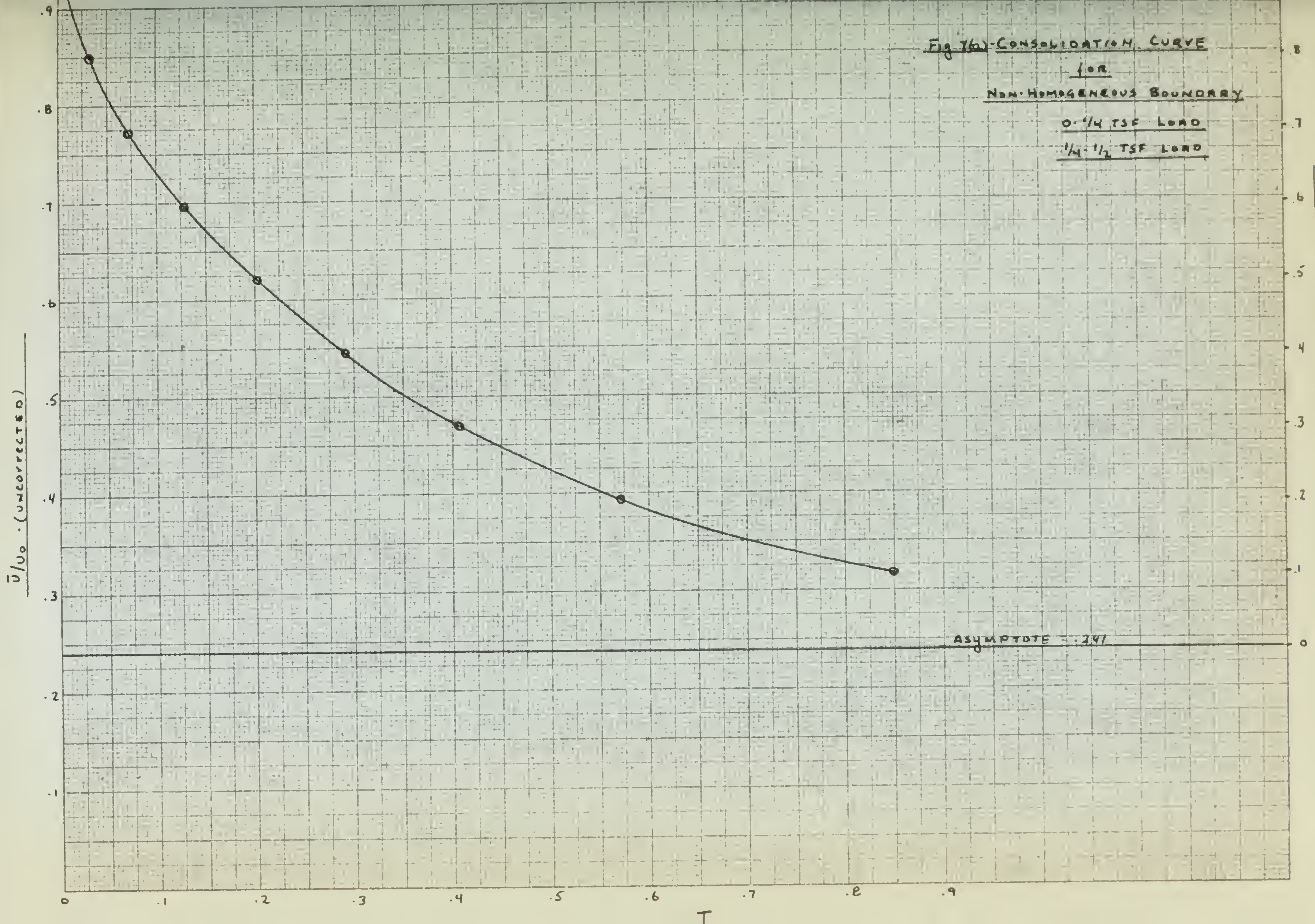


Fig 7(a)·Consolidation Curve
for
Non-Homogeneous Boundary
0-1/4 TSF Load
1/4-1/2 TSF Load
Asymptote = .241
Ū/U₀ ·(Uncorrected)
Ū/U₀ (Corrected) = (1-% Cons.)
T
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
.1
.2
.3
.4
.5
.6
.7
.8
.9

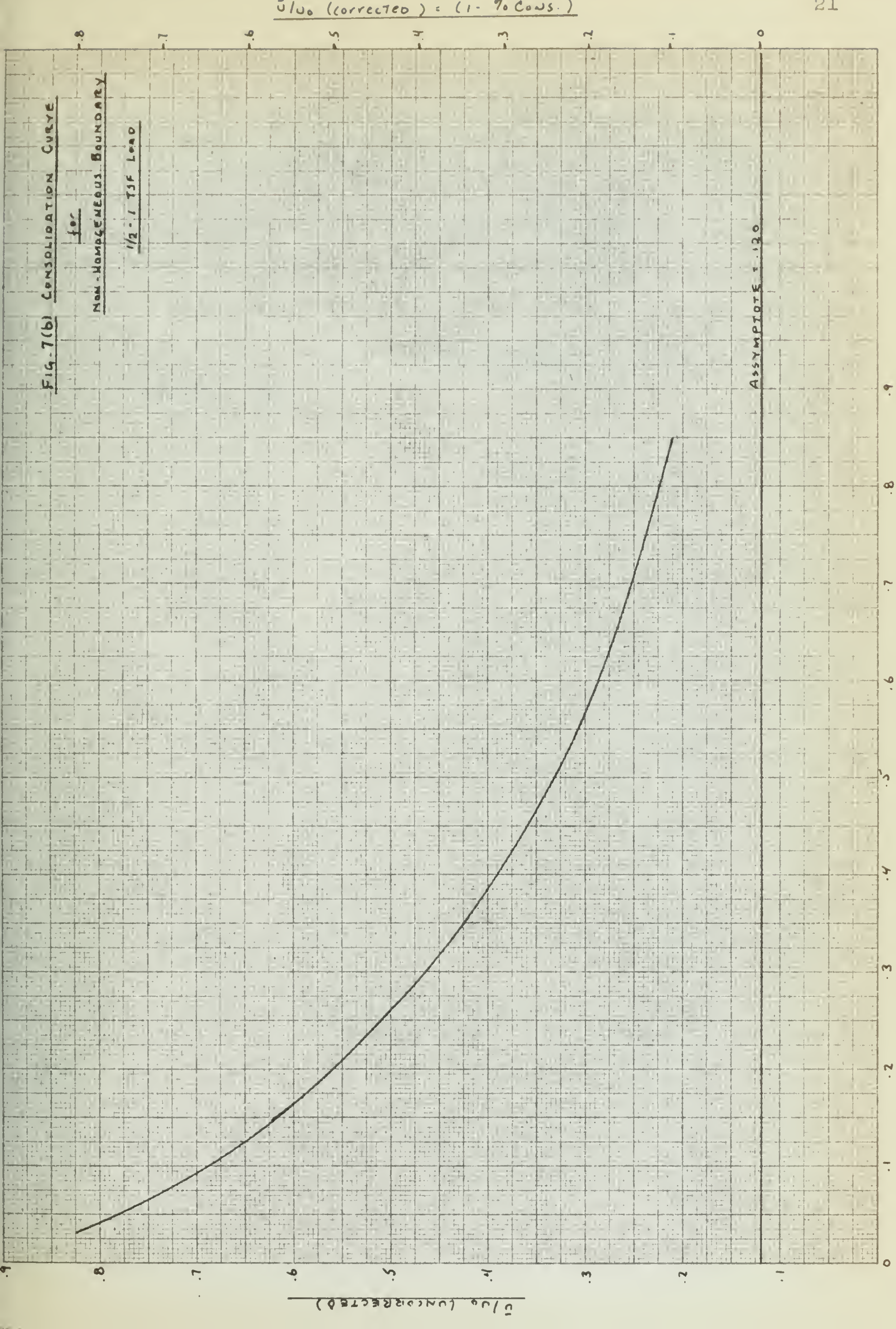


FIG. 7(b) CONSOLIDATION CURVE for NON-HOMOGENEOUS BOUNDARY 1/2-1 TSF LOAD

As may be noted from Figures 6,7a and 7b the solution of the equation gives the same value for the Time Factor as that tabulated by Taylor (8). The basic assumptions of linear variation of hydrostatic excess pressure with depth thus reduces a seemingly involved problem to the use of tabulated values, instead of tedious computations for each variation in Permeameter head.

C. Schiffman Extension to the Theory of Consolidation

Professor Schiffman's development of a three-dimensional anisotropic theory of consolidation (9) provides a working basis for the study herein conducted. His assumptions in developing this theory are:

(1) Complete saturation of Soil Mass

(2) Incompressible fluid

(3) Incompressible soil solids of small particle size

(4) Darcy's Law valid at any instant of time

(5) Change in volume is linear with imposed pressure

(6) Change in volume is small compared to original volume

Consider a prism of soil of volume, V, and surface, S,. In accordance with the law of conservation of mass, the fluid flow into the mass through the surface must equal the total volume change of the mass. In terms of vector functions the total instantaneous mass flow is equal to

$$-\int \vec{V} \cdot n \, ds + \int Q \, dv$$

where $-\int V \cdot n \, ds$ = flow into mass through surface S

and $\int Q \, dv$ = increase in volume due to internal flow generation at rate, Q, due to head

the volume change due to flow is equal to:

$$\frac{\partial v}{\partial t} = \frac{\partial v_v}{\partial t} + \frac{\partial v_s}{\partial t}$$

Equating, we arrive at:

$$\int_v \left[\nabla \cdot (k \nabla h) + Q + \frac{\partial v_v}{\partial t} \right] dv = 0$$

Since the volume is arbitrarily established we can write

$$\nabla \cdot (k \nabla h) + Q + \partial v_v / \partial t = 0$$

Since only those strains due exclusively to volume change are herein considered (assumptions 5 and 6), only normal stresses need be treated. The Modulus of Volume Change, M_v is defined by:

$$m = \frac{\partial v_v}{\partial \theta}$$

Where

$$\theta = \sigma_x + \sigma_y + \sigma_z$$

Since the total pressure or the Soil Mass is composed of the neutral pressure, u, and the effective mean stress $\bar{\theta}$ we can write:

$$\theta = \bar{\theta} + u$$

Where u is the pore pressure defined by:

$$u = \gamma_w h \qquad h = \text{head}$$

Since the consolidation process involves the transfer of initially incurred stress from the water to the soil grains, we can write:

$$\partial \bar{\theta} = \partial u$$

and that:

$$\partial v_v = - m \partial u$$

By substitution in the equation of mass conservation, we then arrive at the differential equation of consolidation for a variable permeability and time-dependent loading:

$$\nabla \cdot (k \nabla u) + Q \gamma_\omega = m \gamma_\omega \frac{\partial u}{\partial t}$$

the treatment of the two dependent variables, k and u, is based upon the work of Schmid (14), who proposes the relationship:

$$\bar{k} = \beta (n - n_0)$$

where β = Constant

n = Porosity

n_0 = Ineffective Porosity

Using this relationship, we can extend it to say that a linear relationship also exists between k and u:

$$k = \alpha u + k_f$$

where

k_f = Coefficient of Consolidation at the end of consolidation

α = Modulus of Permeability Varation

and

$$\alpha = V m$$

It is now feasible to establish a differential equation covering the general theory of consolidation under conditions of varying permeability and time dependent loading:

(a) In terms of excess pore pressure u

$$\alpha(\nabla u)^2 + \nabla u \cdot \nabla k_f + \alpha u \nabla^2 u + k_f \nabla^2 u + Q\gamma_w = m\gamma_w \frac{\partial u}{\partial t}$$

(b) In terms of the permeability k

$$\frac{1}{\alpha}(\nabla k^2) - \frac{1}{\alpha}(\nabla k \cdot \nabla k_f) + \frac{1}{\alpha} k \nabla^2 k - \frac{1}{\alpha} k \nabla k_f + Q\gamma_w = \frac{m\gamma_w}{\alpha}\frac{\partial k}{\partial t}$$

(c) and

$$\nabla k_i \cdot \nabla u - \alpha(\nabla u_o \cdot \nabla u) + \alpha(\nabla u)^2 + \alpha u \nabla^2 u + (k_o + \alpha u_o)\nabla^2 u$$

$$+ Q\gamma_w = m\gamma_w \frac{\partial u}{\partial t}$$

The present study being limited to the consideration of one-dimensional consolidation, the general equation for such a case can be written:

$$\left(C_o + \frac{\alpha u_o}{m\gamma_w}\right)\frac{\partial^2 u}{\partial z^2} - \frac{\alpha}{m\gamma_w} u \frac{\partial^2 u}{\partial z^2} - \frac{\alpha}{m\gamma_w}\left(\frac{\partial u}{\partial z}\right)^2 + R = \frac{\partial u}{\partial t}$$

where

R = Rate of change of imposed excess pore pressure

C = Coefficient of Consolidation at start of consolidation.

This equation can be written under the following conditions

(1) Double Drainage

(2) Infinite extent of soil mass horizontally

(3) Finite thickness of soil mass

(4) Uniform initial Coefficient of Permeability

(5) Uniform initially imposed pore pressure

Professor Schiffman has presented several individual solutions involving the following problems:

(1) Constant permeability and general time dependent loading

(2) Constant permeability and linear loading

(3) Constant Permeability and construction loading

(4) Constant Permeability and harmonic loading

(5) Variable permeability

His solutions to these problems are as follows:

(1) Constant Permeability - time dependent loading

$$u(z,t) = \frac{1}{H} \sum_{n=1}^{\infty} \left[\int_0^{2H} \sigma(z) \sin \frac{n\pi z}{2H} dz \right] e^{-\frac{cn^2\pi^2}{4H^2} t} \sin \frac{n\pi z}{2H}$$
$$+ \frac{1}{H} \sum_{n=1}^{\infty} \sin \frac{n\pi z}{2H} \left\{ \int_0^t \left[\int_0^{2H} R(z,t) \sin \frac{n\pi z}{2H} dz \right] e^{-\frac{cn^2\pi^2}{4H^2}(t-\tau)} d\tau \right.$$

(2) Constant Permeabilty - linear loading

$$u(z,t) = \frac{16 u_0}{T_0 \pi^3} \sum_{n=1,3,5}^{\infty} \frac{1}{n^3} \sin \frac{n\pi}{2H} \left(1 - e^{-\frac{n^2\pi^2}{4} T}\right)$$

Since the average pore pressure can be expressed as:

$$\bar{u}(T) = \frac{1}{2H} \int_0^{2H} u(z,t)\, dz$$

Then by substitution

$$\bar{u}(T) = \frac{32 \bar{u}_0}{T_0 \pi^4} \sum_{n=1,3,5\cdots}^{\infty} \frac{1}{n^4} \left(1 - e^{-\frac{n^2\pi^2}{4} T}\right)$$

Where T is a dimensionless Time Factor

$$T = \frac{c}{H^2} t$$

Figure 8a shows the curve developed from a computation based on this equation, from which all other computations for the linear case can be made.

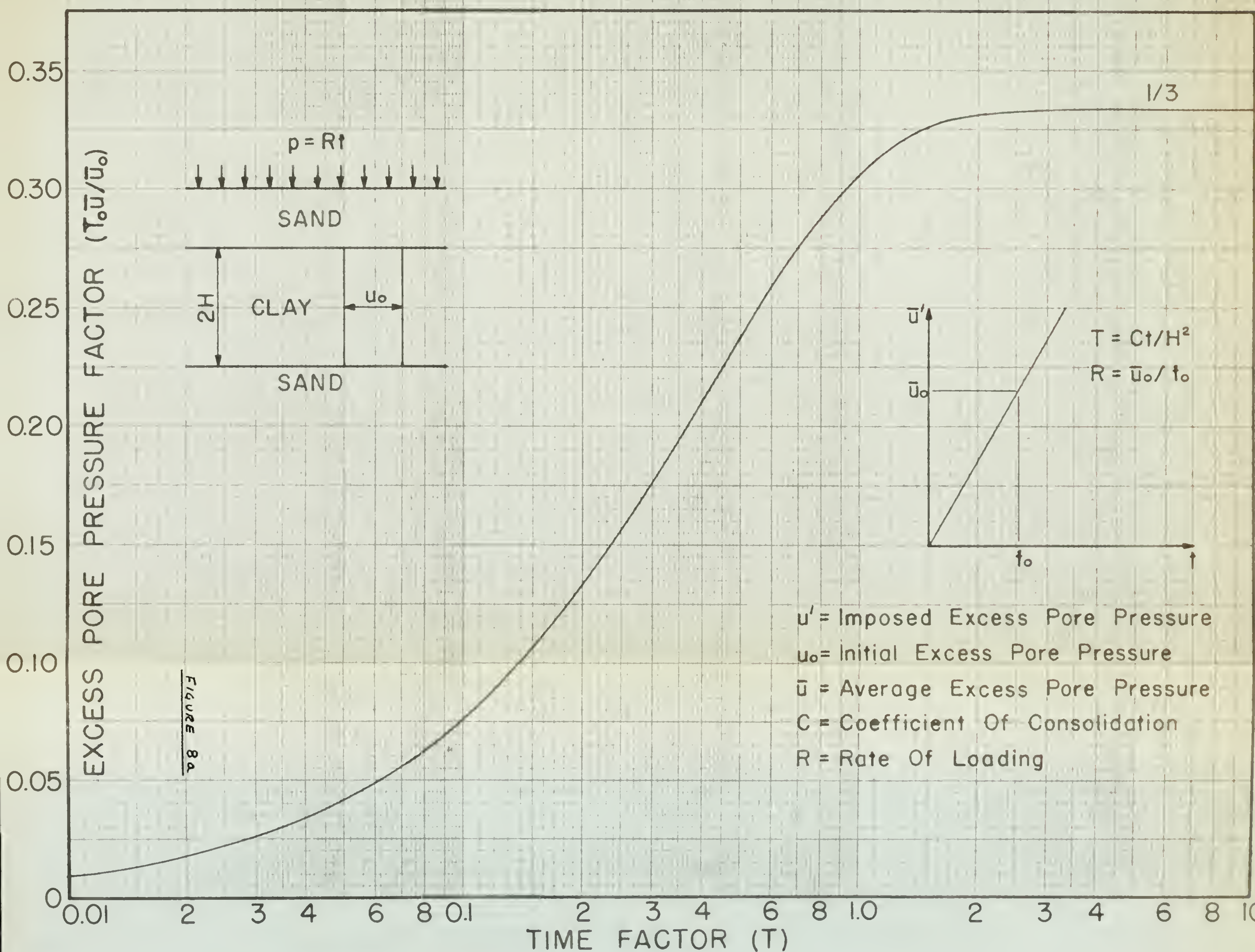

1/3
p = Rt
SAND
CLAY
2H
u_o
SAND
$\bar{u}'$
$\bar{u}_o$
t_o
t
T = Ct/H²
R = ū₀/t₀
u' = Imposed Excess Pore Pressure
u_o = Initial Excess Pore Pressure
ū = Average Excess Pore Pressure
C = Coefficient Of Consolidation
R = Rate Of Loading
EXCESS PORE PRESSURE FACTOR (T₀ū/ū₀)
TIME FACTOR (T)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0.01
2
3
4
6
8
0.1
2
3
4
6
8
1.0
2
3
4
6
8
10

FIGURE 8a

Figure 8 (b) presents the computation involving the linear loading period ending at time t_o and the amount of excess pore pressure dissipated at that time. The percentage of settlement completed is equivilent to the amount of excess pore pressure dissipated and thus the settlement at the end of a linear type construction loading period can be computed.

As an example of the usefulness of Figure 8b, let us consider a structure founded on a clay structum with $C_v = 1.5\ \mathrm{cm^2/min}$ If, then, the length of construction is related to the end time factor To:

$$t_o = 172\ T_o \text{ DAYS}$$

by entering Figure 8b, a table of percentage of settlement dissipated can be constructed, in terms of the length of construction. Table 1 shows this construction as developed by Professor Schiffman.

By use of such tables, the engineer can now make a rational decision as to the desired construction time period which will restrict post-construction settlements to satisfactory values, or as to selection of alternate solutions.

(3) Constant Permeability-Construction Loading

With the results of the previous sections available, the pore pressure can now be analyzed at any instant and for any construction period. Figure 8c presents a typical load-time diagram for construction loading, wherein a load Γ_o is imposed at time t_o , the end of a linear construction period.

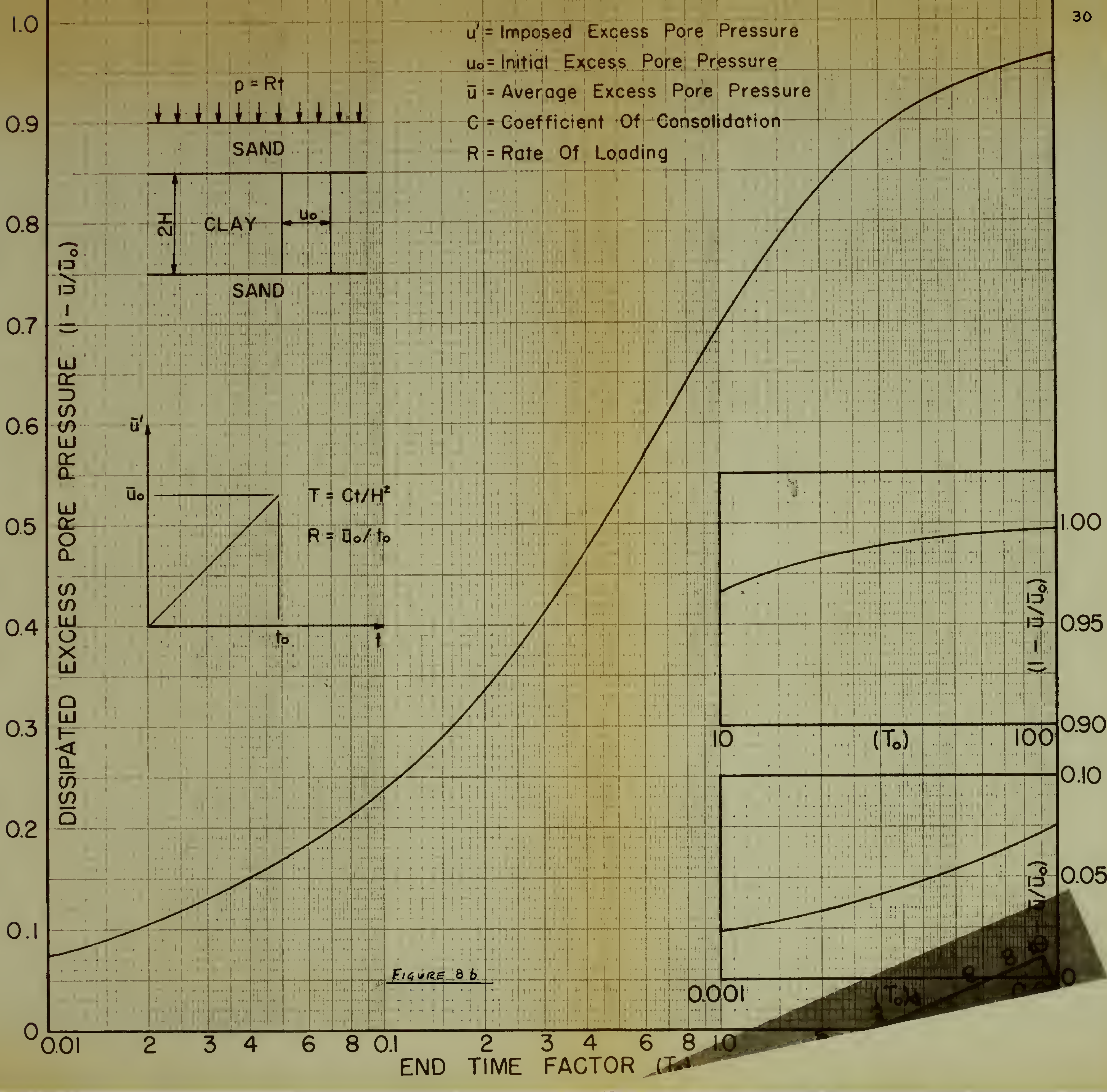

u' = Imposed Excess Pore Pressure
u_o = Initial Excess Pore Pressure
$\bar{u}$ = Average Excess Pore Pressure
C = Coefficient Of Consolidation
R = Rate Of Loading
p = Rt
SAND
CLAY
2H
u_o
SAND
$\bar{u}'$
$\bar{u}_o$
$T = Ct/H^2$
$R = \bar{u}_o/t_o$
t_o
t
DISSIPATED EXCESS PORE PRESSURE $(1 - \bar{u}/\bar{u}_o)$
END TIME FACTOR
(T_o)
$(1 - \bar{u}/\bar{u}_o)$
1.00
0.95
0.90
0.10
0.05
0
10
100
0.001
(T_o)

FIGURE 8 b

TABLE 1

EXAMPLE OF SETTLEMENT DISSIPATED DURING A LINEAR CONSTRUCTION PERIOD

$H = 20$ ft

$\dot{C} = 1.5\ cm^2/min$

% SETTLEMENT DISSIPATED	T_o	t_o
5	.00435	.75
10	.018	3
20	.071	12
30	.16	28
40	.28	49
50	.45	78
60	.68	117
70	1.03	177
80	1.65	284
90	6.20	559
95	6.70	1153

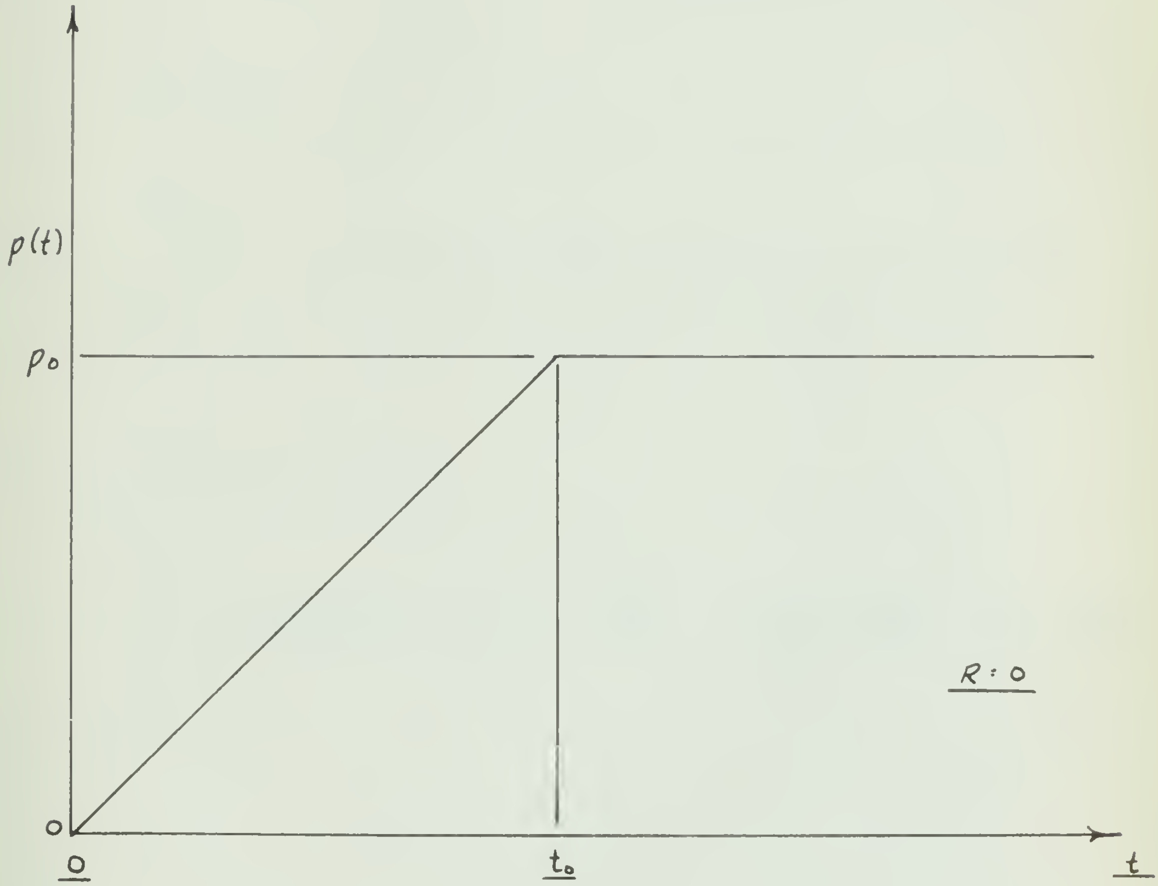


FIG. 8C LOAD - TIME DIAGRAM FOR CONSTRUCTION LOADING

Treatment of this problem is as described in (2) above.

Figure 8d and 8e present the solution of the determination of average pore pressure during and after construction. These curves can be used to determine the theoretical consolidation curve in the following manner:

(1) Estimate the construction time

(2) Determine the Coefficient of Consolidation from Laboratory tests

(3) Determine To from the Coefficient of Consolidation

(4) Enter Figures 8d and 8e and select proper Consolidation Curve

(4) <u>Variable Permeability</u>

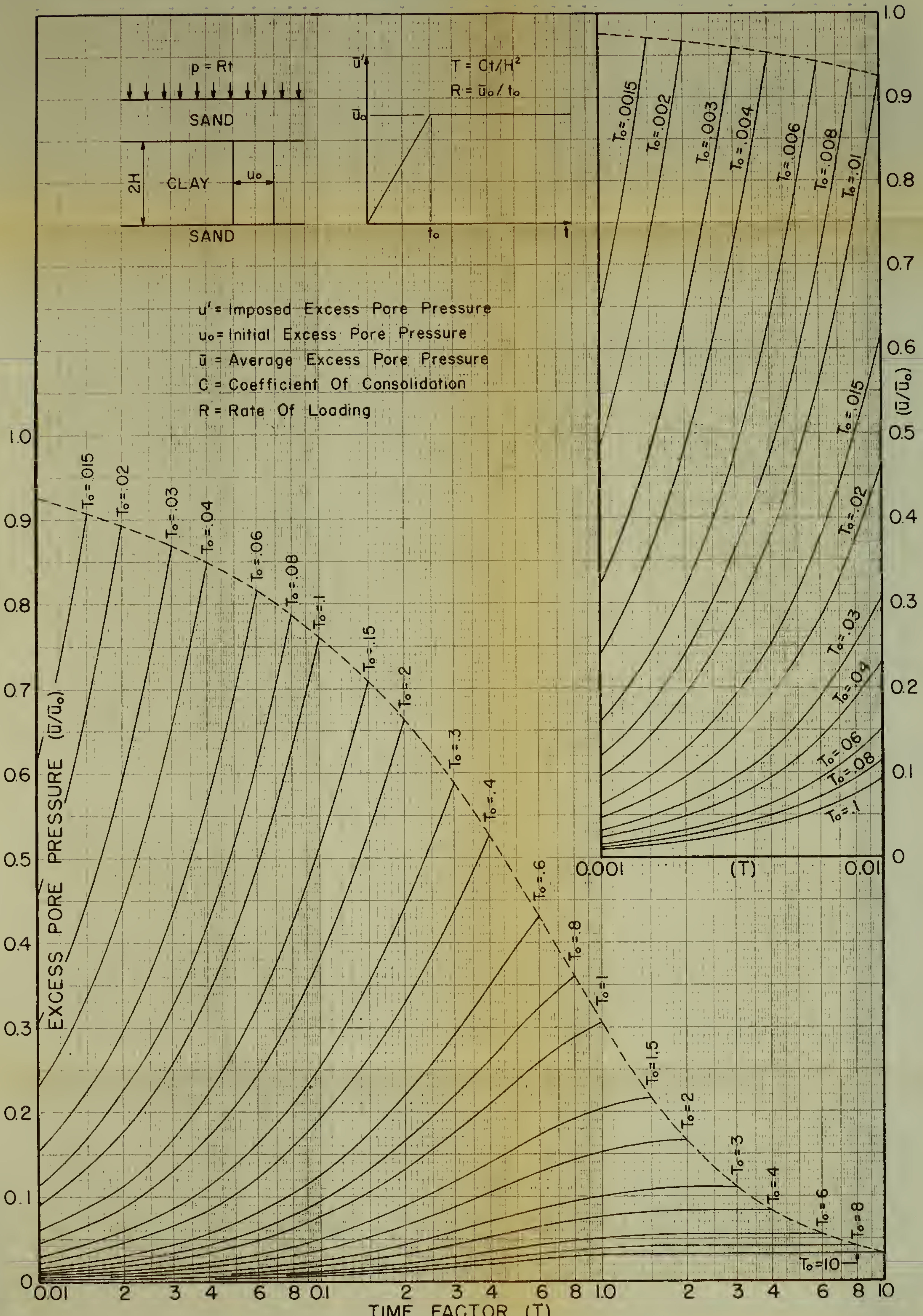
The basic equation governing this case is:

$$\left(C_0 + \frac{\alpha u_0}{m\gamma_w}\right)\frac{\partial^2 u}{\partial z^2} - \frac{\alpha}{m\gamma_w}u\frac{\partial^2 u}{\partial z^2} - \frac{\alpha}{m\gamma_w}\left(\frac{\partial u}{\partial z}\right)^2 + R = \frac{\partial u}{\partial t}$$

However, the solution of this equation is hampered by its non-linearity, for which general techniques of solution are unavailable. Solution by approximation techniques is therefore utilized, in lieu of numerical computation by analogue or digital computer methods.

The incremental time approximation is first considered. It is assumed the permeability remains constant over a finite time increment, but that the permeability varies from one increment to the next. For a finite number of time increments we have:

$$u(z,T') = \frac{4u_0}{\pi}\sum_{n=1,3,5\cdots}^{\infty}\frac{1}{n}\sin\frac{n\pi}{2H}z\,e^{-\frac{n^2\pi^2}{4}T'}$$



p = Rt
SAND
CLAY
2H
u_o
SAND
$\bar{u}'$
$\bar{u}_o$
t_o
t
T = Ct/H²
R = $\bar{u}_o$ / t_o
u' = Imposed Excess Pore Pressure
u_o = Initial Excess Pore Pressure
ū = Average Excess Pore Pressure
C = Coefficient Of Consolidation
R = Rate Of Loading
EXCESS PORE PRESSURE ($\bar{u}/\bar{u}_o$)
TIME FACTOR (T)
($\bar{u}/\bar{u}_o$)
(T)

FIGURE 8d

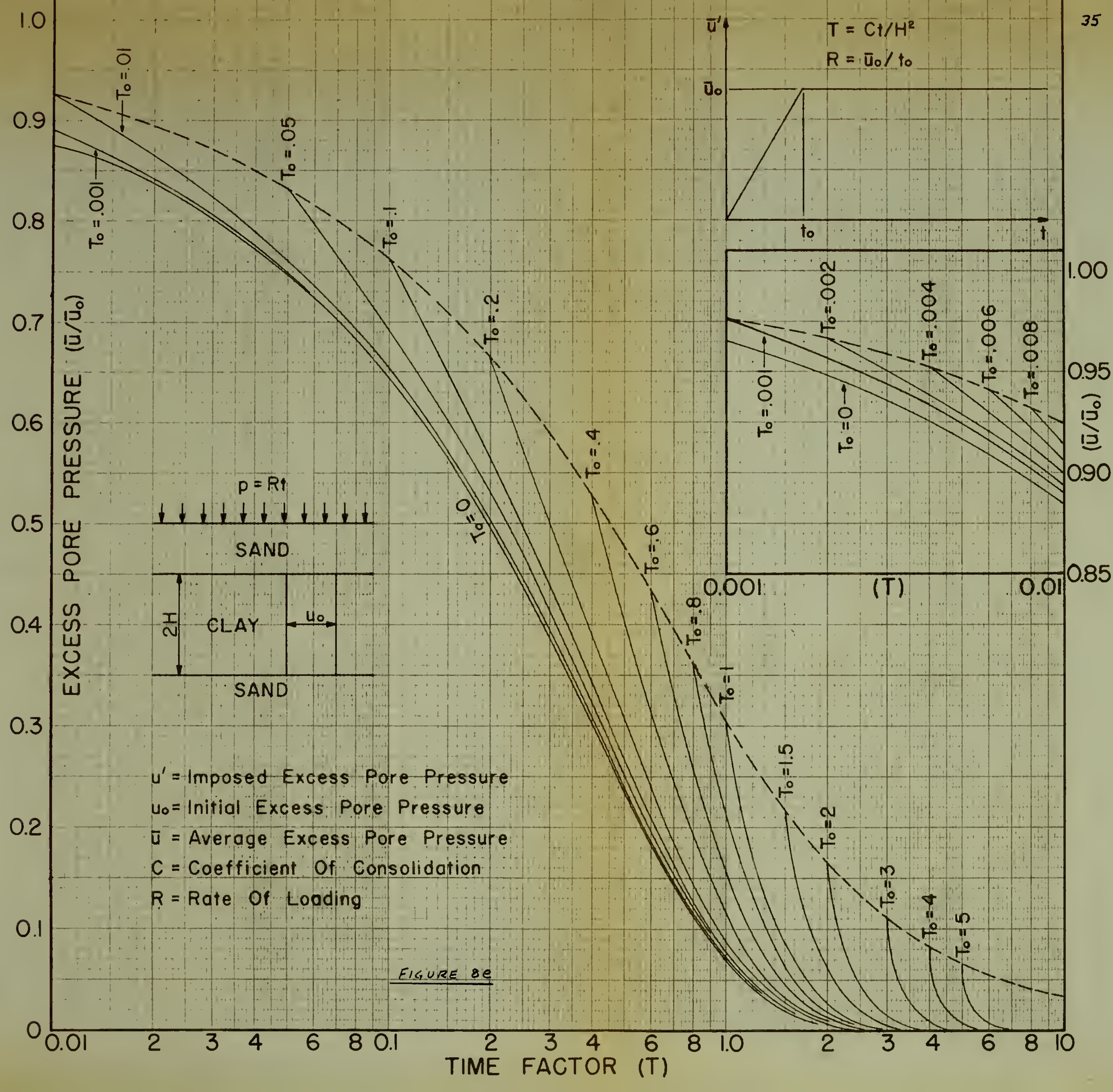

EXCESS PORE PRESSURE $(\bar{u}/\bar{u}_o)$
TIME FACTOR (T)
$T = Ct/H^2$
$R = \bar{u}_o/t_o$
$\bar{u}'$
$\bar{u}_o$
t_o
t
p = Rt
SAND
CLAY
2H
u_o
SAND
u' = Imposed Excess Pore Pressure
u_o = Initial Excess Pore Pressure
$\bar{u}$ = Average Excess Pore Pressure
C = Coefficient Of Consolidation
R = Rate Of Loading
$T_o = .001$
$T_o = .01$
$T_o = .05$
$T_o = .1$
$T_o = .2$
$T_o = .4$
$T_o = .6$
$T_o = .8$
$T_o = 1$
$T_o = 1.5$
$T_o = 2$
$T_o = 3$
$T_o = 4$
$T_o = 5$
$T_o = 0$
$T_o = .002$
$T_o = .004$
$T_o = .006$
$T_o = .008$
0.001
(T)
0.01
1.00
0.95
0.90
0.85
0.01
0.1
1.0
10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

FIGURE 8E

$$\bar{u}(T') = \frac{8u_o}{\pi^2} \sum_{n=1,3,5\cdots}^{\infty} \frac{1}{n^2} e^{-\frac{n^2\pi^2}{4}T'}$$

$$T' = \frac{1}{H^2}\left[c_1 t_1 + c_2(t_2 - t_1) + c_3(t_3 - t_2) + \cdots c_m(t - t_m)\right]$$

By fitting incremental laboratory test curves to the theoretical curve, on the basis of theoretical values of u and t', successive values of the bracketed term can be determined. The degree of accuracy desired can be controlled by the number of increments utilized in the fitting procedure.

A second approximation considers that an exponential permeability pore-pressure relationship will approximate the linear condition originally assumed, over the entire range of the consolidation process. The governing differential equation is:

$$B\frac{\partial^2 k}{\partial z^2} = \frac{\partial k}{\partial t}$$

With boundary conditions:

(a) $k(0,t) = k_f$

(b) $k(z,H,\theta) = k_f$

(c) $k(z,0) = \alpha u_o + k_f$

The solution is: $k(z,t) = k_f + \frac{4\alpha u_o}{\pi} \sum_{n=1,3,5\cdots}^{\infty} \frac{1}{n} \sin\frac{n\pi}{2H} z e^{-\frac{n^2\pi^2}{4H^2}BT}$

which when converted back to excess pore pressure is:

$$u(z,t) = \frac{4u_o}{\pi} \sum_{n=1,3,5\cdots}^{\infty} \frac{1}{n} \sin\frac{n\pi}{2H} z e^{-\frac{n^2\pi^2}{4H^2}BT}$$

where B is the Coefficient of Consolidation Permeability and is equal to:

$$B = \frac{k_o - k_f}{n m \gamma_w}$$

where

$$\eta = \ln \frac{k_o}{k_f}$$

The solution to the general case for one-dimensional consolidation can be utilized for varying permeability, if a new Time Factor V is substituted for T where:

$$V = \frac{B}{H^2} T$$

It is noted that as k_o approaches K_f the value of B approaches C_c

It is essential, in this solution, to satisfy the condition that the soil have an initial and final coefficient of permeability, which is constant throughout the mass and at terminal points in any segment.

D. Permeability

The property of soil, concerned with the facility of travel of water through a soil mass, is termed Permeability. Since the physical properties of soils as well as the state of stress of the pore water have important effects on the mechanical behavior of a soil mass, it can be seen that this property is of major interest in the study of consolidation characteristics of soils.

The extremely small pore sizes encountered in most soils cause any flow of water through the soil mass to be laminar in nature, (i.e. the amount of head lost in friction is directly proportional to the velocity of flow). Such laminar flow takes place in accordance with dynamical eqations of motion which by analysis of various simple channel shapes have been reduced to usable formulas. In engineering problems the flow through individual flow channels is not required, but it is rather the average flow through the soil mass which is important.

H. Darcy in 1856 demonstrated experimentally that the velocity of pore-water flow through a soil mass is directly proportional to the hydraulic gradient thus formulating the basic law of flow

$$V = k i$$

where v = Velocity of flow

k = Coefficient of Permeability

i = Hydraulic Gradient

The flow velocity, thus defined, is the superficial velocity through the soil mass, not the specific velocity through each flow channel.

To evaluate the coefficient of Permeability directly, the use of a constant head permeameter provides a quick, simple solution. Consider a soil sample with cross-sectional area, A, and height, L. Let there be a supply of water at constant elevation, H, above the sample, and let there be some means of measuring flow volume through the sample. With these values known. Darcy's Law can be re-written:

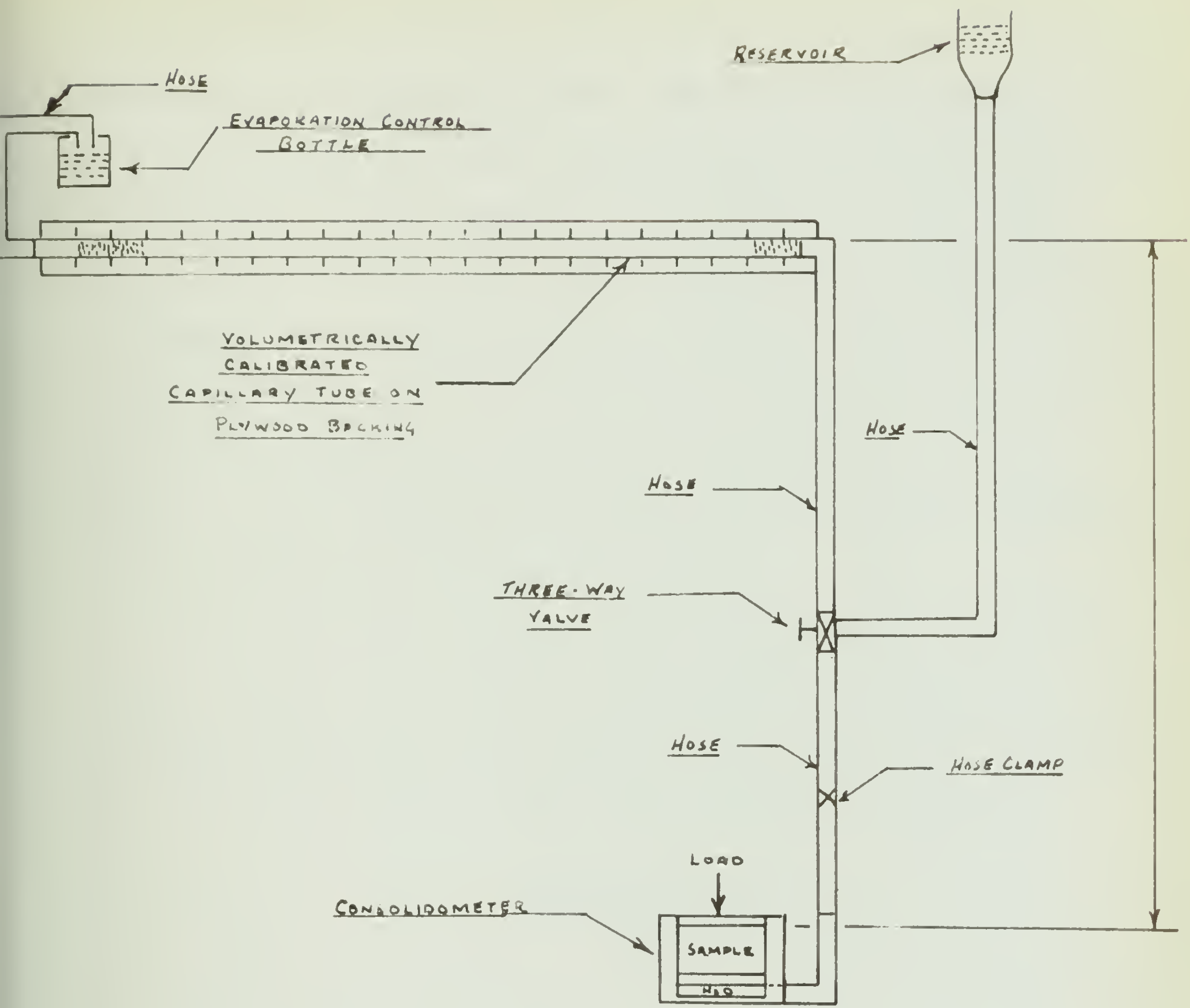
$$V = \frac{q}{A} = ki \qquad \text{whence} \qquad k = \frac{q}{iA} = \frac{qL}{AH} = \frac{QL}{AtH}$$

where Q = Total Volume of Flow and t = time.

The use of a constant-head permeameter has been restricted to soil types of relative coarse grading, since flow volume through fine grained soil is small. However by continuous measurement of flow volume during a consolidation test with the apparatus shown in Figure 9, flow volume measurement is a simple matter. In addition to the obvious advantages of consolidation-time values for flow volume, this apparatus eliminates the problems of air-pressure application encountered by Peterson (12) in using a variable head permeameter to measure flow through an Illite sample. In addition it makes possible, an almost instantaneous evaluation of permeability at any small finite time interval.

CONSTANT HEAD PERMEAMETER

SCHEMATIC



OPERATING PROCEDURE

1 - CLEAR SYSTEM OF AIR BY FILLING CONSOLIDOMETER BASE WITH DISTILLED WATER, AND APPLYING VACUUM TO END OF CAPILLARY TUBE BY MEANS OF EVAPORATION CONTROL HOSE. CHECK FOR AIR IN RESERVOIR HOSE BY OPENING 3-WAY VALVE TO FEED INTO CAPILLARY TUBE.

2 - CLAMP HOSE WITH HOSE CLAMP

3 - PLACE SAMPLE IN CONSOLIDOMETER

4 - APPLY LOAD UNTIL 1/2 TSF IS ON SAMPLE

5 - WHEN 1/2 TSF IS ON SAMPLE, OPEN HOSE CLAMP.

6 - NOTE VOLUMETRIC READINGS ON PERMEAMETER, CONCURRENTLY WITH CONSOLIDATION READINGS

7 - REFILL PERMEAMETER DURING TEST AS REQUIRED.

FIG. 9

The evaluation of the coefficient of permeability obtained by use of the apparatus described above is a function of (1) the porosity of the soil mass (2) the shape and size of the voids and (3) the density and viscosity of the fluid. Since we are dealing with a pure Kaolin Clay, laminar flow may be assumed. In dealing with the porosity of fine grained soils, it must be noted that the flow channel cross-sectional area is reduced by the amount of ionically "bound" water which is adsorbed on the surface of the soil particles and, being immovable, blocks part of the flow path.

The work of Schmid (13) indicates that the effect of this "bound" water can be reflected in an extension to the well-known Hagin-Poiseulle equation for laminar flow through a tube of constant cross-section (8). Schmid's equation:

$$k = \frac{\gamma_w D_E^2 (n - n_o)}{32 \mu}$$

Where γ_w = unit wt. of water

D_E = Effective Diameter of Soil Particles

n = Porosity of Soil

n_o = ineffective Porosity i.e. channels blocked by "bound" water

μ = coefficient of viscosity of water

indicates that the coefficient of permeability is directly

proportional to the "effective" porosity, $(n - n_o)$. This concept would appear at variance with the experimental data compiled by numerous investigators, which shows that plot of k vs log e as a straight line, i.e. an exponential relationship. However as Schmid points out, the basic relationship, $n = \frac{e}{1+e}$ is actually only an approximation of the series expansion of the function $\log \frac{1}{n}$ or $\log \frac{e+1}{e}$, which ignores the higher order terms. In actuality the relationship between n and e is logarithmic and thus Schmid's work can be reconciled with other investigators' work if this factor is recognized. The error involved in ignoring the higher order terms is less than 10% and decreases rapidly with increasing void-ratio.

The straight-line relationship between porosity and the coefficient of permeability does not hold in the region $n \approx n_o$ and Schmid indicates that such deviation can be expected, since in deriving his equation he made two approximating assumptions:

(1) That the effective diameter, D_ε , is constant.

(2) That the ineffective porosity, n_o , is constant.

which are never achieved in actual testing. It is further suggested that the consolidation process, by virtue of its reduction in rate of porosity change at large loading increments, would indicate that such deviation should be expected in such regions. Since these regions are the same

as where $n \approx n_o$. The straight-line relationship would thus be invalid for larger load increments where porosity changes are small relative to the applied load.

The accurate evaluation of the coefficient of permeability, during the consolidation process, is of extreme importance, since the simplifying assumptions of both Terzaghi and Schiffman, include k as a constant for the one-dimensional drainage conditions considered herein. The determination of the manner of variance of k with decreasing porosity under consolidation loading would be of assistance in the solution of the more complicated time-and-space dependent consideration of the consolidation process as proposed by Schiffman. Toward this end the evaluation of k during the consolidation process will be attempted as part of this work.

PART 111

MATERIALS AND APPARATUS

The soil samples used in the conduct of this investigation were prepared from oven-dried pure Kaolin clay secured from WARD'S NATURAL SCIENCE CORP., Rochester, N.Y. under the sample designation "Kaolinite-Dry Branch Ga. Dana #492". This relatively pure clay mineral exhibited a very sensitive reaction to moisture, as noted during the tests for determination of the liquid limit, where the addition of a few drops of distilled water changed the blow count by 10.

For the conduct of the control test, Number 1, a standard Fixed Ring Consolidometer as shown in Figure 10 was utilized.

The application of time-dependent loading to the samples during tests Number 2, 3, 4 ~~and 5~~, was accomplished by means of the apparatus shown in Figure 11. A Conbel Model No. 350 Consolidometer was adapted for use with a King Manufacturing Company visual bleed. The visual bleed, referred to throughout as a time-dependent loading device, was filled to within approximately one and one-half ($1\frac{1}{2}$) inches of the air outlet with a high-quality brake fluid. The pressure accumulator and bellows on the Conbel equipment were also filled with brake fluid in accordance with the manufacturers instructions.

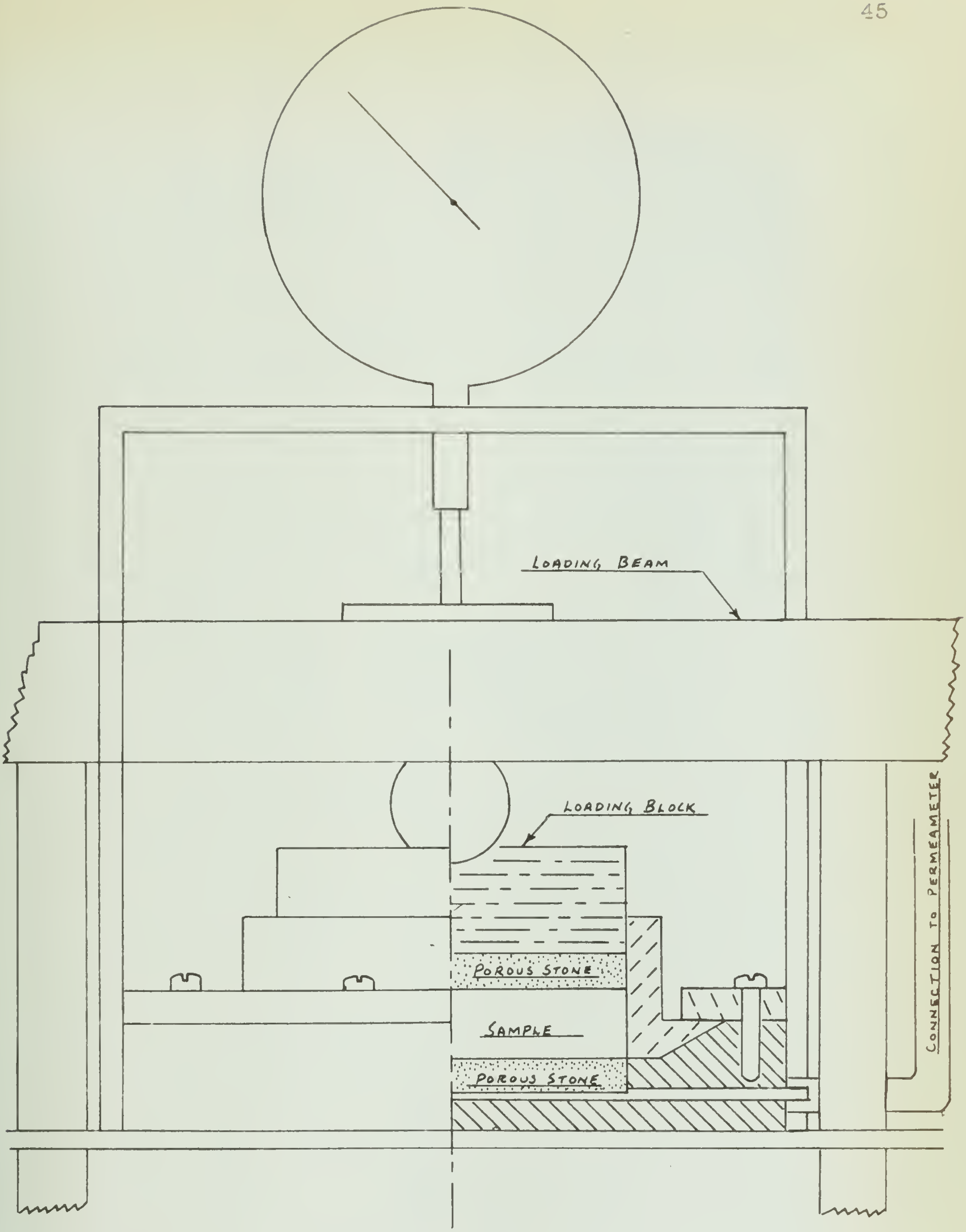


FIG. 10 STANDARD FIXED RING CONSOLIDOMETER (FULL SCALE)

SCHEMATIC

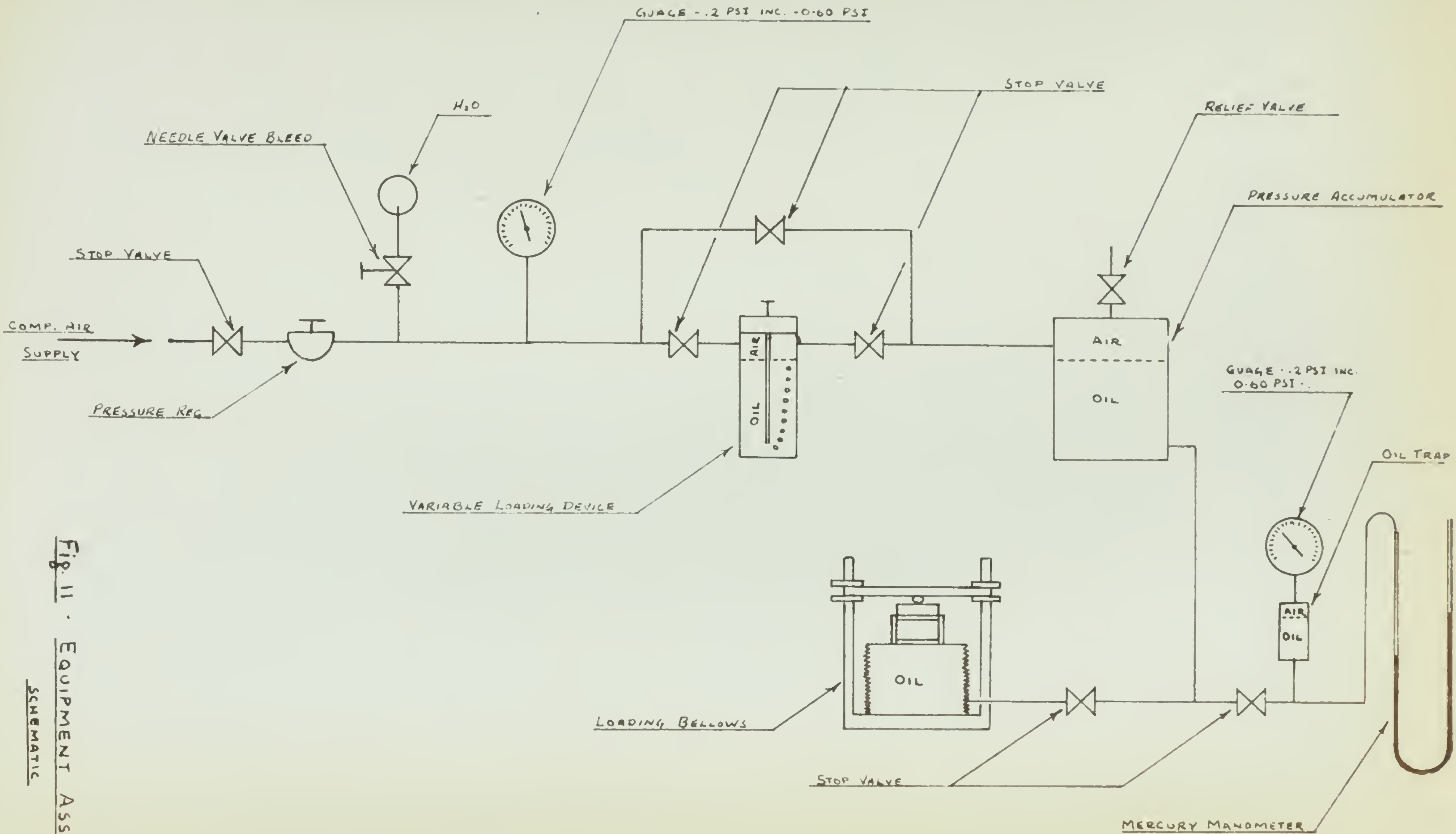


Fig. 11 · EQUIPMENT ASS'Y

SCHEMATIC

For the direct measurement of permeability during all tests conducted, a constant head permeameter as shown in Figure 9 was constructed and utilized.

PART IV

Testing Procedure

A. Preparation of Sample

All samples were prepared at the Liquid Limit determined in accordance with ASTM "Standard Method of Test for Liquid Limit of Soils", ASTM Designation D-423-39. Flow Curves used in determining the Liquid Limit are shown in Figure 12. Reproducibility of the Liquid Limit in mixing the sample prior to testing was considered to be satisfactorily attainable by use of the Standardized Spatula Method, as may be evidenced by the moisture content deviation being less than 1% for all samples. The electric mixing of samples as proposed by Edmonds and Warren (10) was attempted but not utilized since the entrainment of air within the sample appeared excessive.

The sample was placed as follows: a 200 gram. dry weight, sample was prepared at 3% above the Liquid Limit and transferred from the evaporating dish to an open plastic cylinder 4 inches in height and 2.500 inches in diameter. The cylinder was sealed by a metal plate at one end and beaten strongly against a solid surface, concurrently rotating and tapping the sides of the cylinder with a metal rod. Entrapped air is visibly removed during this process. The sample is then extruded by means of a porous stone piston on to a glass plate covered with a filter paper. The planar surface, produced by extrusion into the glass plate, is then forced into the fixed ring and the sample accurately trimmed to the ring size.

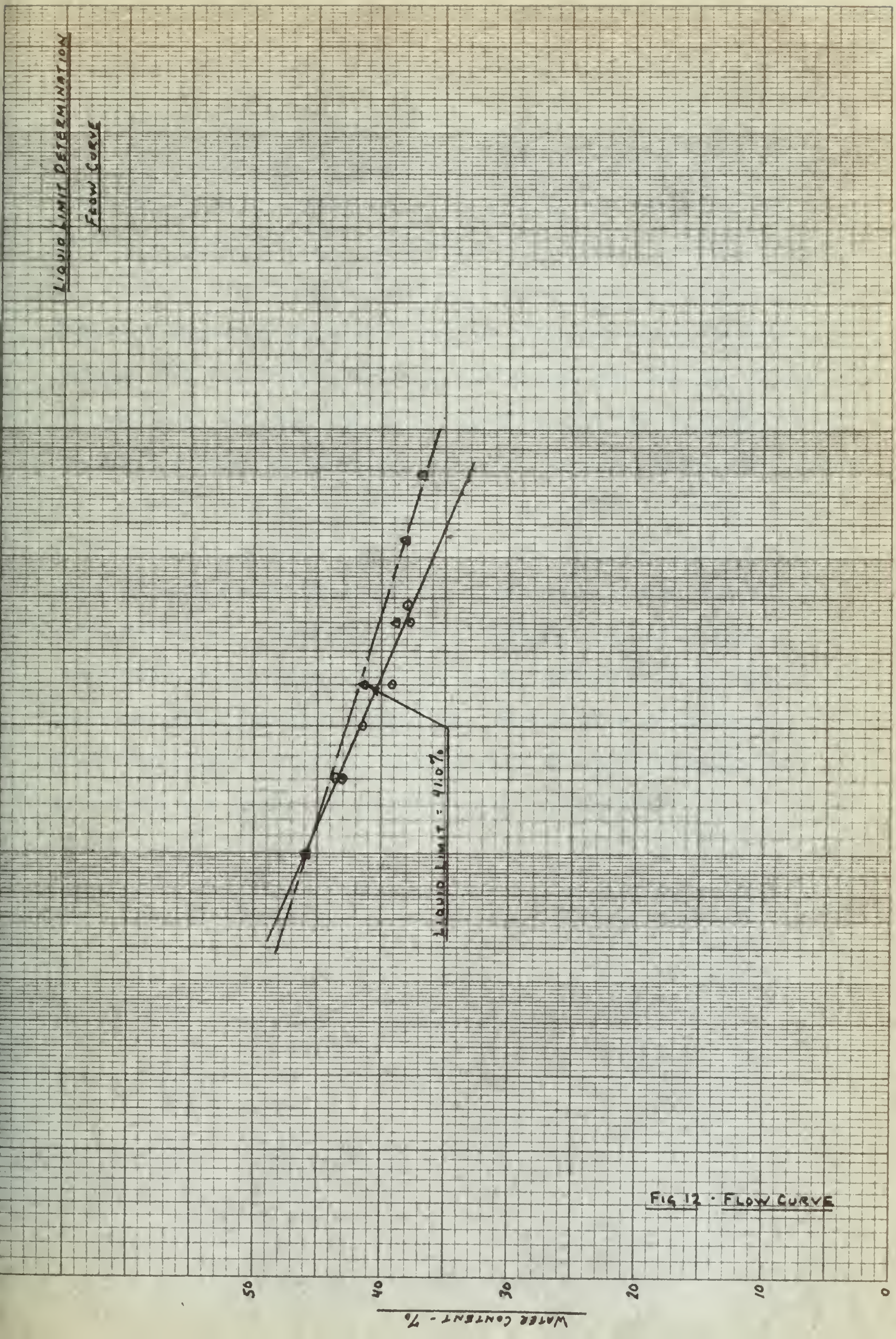


FIG 12 · FLOW CURVE

B. Standard Consolidation Test

Test No. 1 was conducted on a standard Fixed Ring consolidometer as described in Part 111. As suggested by Professor Burmister (11) this test was used as a pilot study to establish techniques of sample preparation and testing. Since no apparent swelling resulted from immersion of the sample, and the strain did not exceed .02 in. per in. it was decided that the testing cycle shown in the raw data sheets of Appendix 1 would be satisfactory. It is to be noted that there is a dearth of literature on the preparation of disturbed samples for consolidation testing, which factor makes a pilot test of this nature an absolute necessity for any testing of such materials. Appendix 1 also includes raw data from a concurrant pilot test conducted by V. McGuffey on the same material with the same equipment. McGuffey's results show that reproducible results can be attained if technique and procedure are carefully analyzed and correlated.

C. Time Dependent Loading Tests

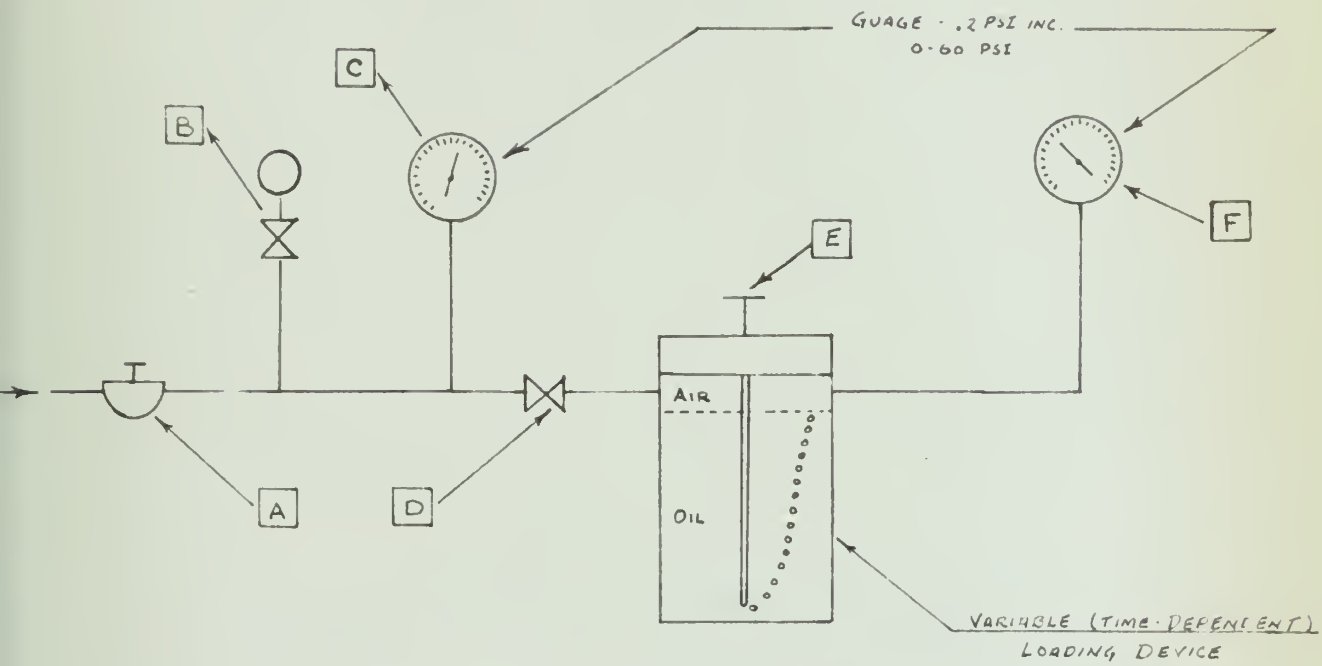
Tests No. 2 and 3 were conducted using the apparatus described in Part 111. The Conbel equipment was calibrated by the uso of dead weights vs. air pressure and it was determined that the calibration charts furnished by the manufacturer were accurate to within one pound of load applied to the sample in the 1-2 ton range. It is suggested that future calibrations of this equipment be accomplished by a proving ring with a planar upper surface to insure axial loading. Attempts to calibrate the equipment with standard laboratory proving rings were unsuccessful, due to the tilting of the bellows at pressures above 4 psi due to lack of axial resistance to load by the proving ring.

Figure 13 shows the calibration procedure followed for the time-dependent loading device. Tables 2 and 3 indicates calibration pressures and data in tabular form.

Figure 14 indicates the operational procedure followed in applying time dependent loading to the sample by means of the time-dependent loading device.

Raw data showing pressure increments and loading cycle times are contained in Appendix 2 and 3.

CALIBRATION PROCEDURE
FOR
VARIABLE LOADING DEVICE
SCHEMATIC



PROCEDURE

1. CLOSE D
2. ADJUST A TO DESIRED INITIAL PRESSURE
3. ADJUST B UNTIL C READS DESIRED INITIAL PRESSURE
4. READ C AND F, NOTE READINGS
5. OPEN D, NOTE TIME
6. COUNT NUMBER OF BUBBLES PER MINUTE FOR VARIOUS SETTINGS OF E
7. NOTE TIME THAT READING ON F EQUALS READING ON C
8. NUMBER OF BUBBLE PER MINUTE CORRELATES TIME-RATE OF PRESSURE BUILD-UP BETWEEN C AND F

FIG. 13

TABLE 2

CALIBRATION OF LOADING BELLOWS

CHECK CALIBRATION		MANUFACTURER'S CALIBRATION	
WEIGHT lbs	GAGE PSI	WEIGHT ON BELLOWS - lbs	GAGE PSI
30	1.45	30	1.50
40	1.80	40	1.80
50	2.20	50	2.25
60	2.62	60	2.65
70	3.05	70	3.05

EQUIVILENT LOAD ON SAMPLE - GAGE PRESSURE

LOAD ON 2½ IN. SAMPLE TONS/SF	LOAD ON 2½ IN. SAMPLE lbs	GAGE PRESS. PSI	AREA OF 2½ IN SAMPLE SQ. IN.
.25	17.0	.75	4.909
.50	34.1	1.5	
1	68.2	3.0	
2	136.4	6.0	
4	272.7	12.0	
8	545.4	24.0	

CORRECTION FOR BELLOWS EXPANSION

CONSOLIDATION OF SAMPLE IN.	CORRECTION ADD IN	CONSOLIDATION OF SAMPLE IN	CORRECTION ADD IN
.025	.1	.125	.5
.05	.2	.150	.6
.075	.3	.175	.7
.10	.4	.200	.8

TABLE 3

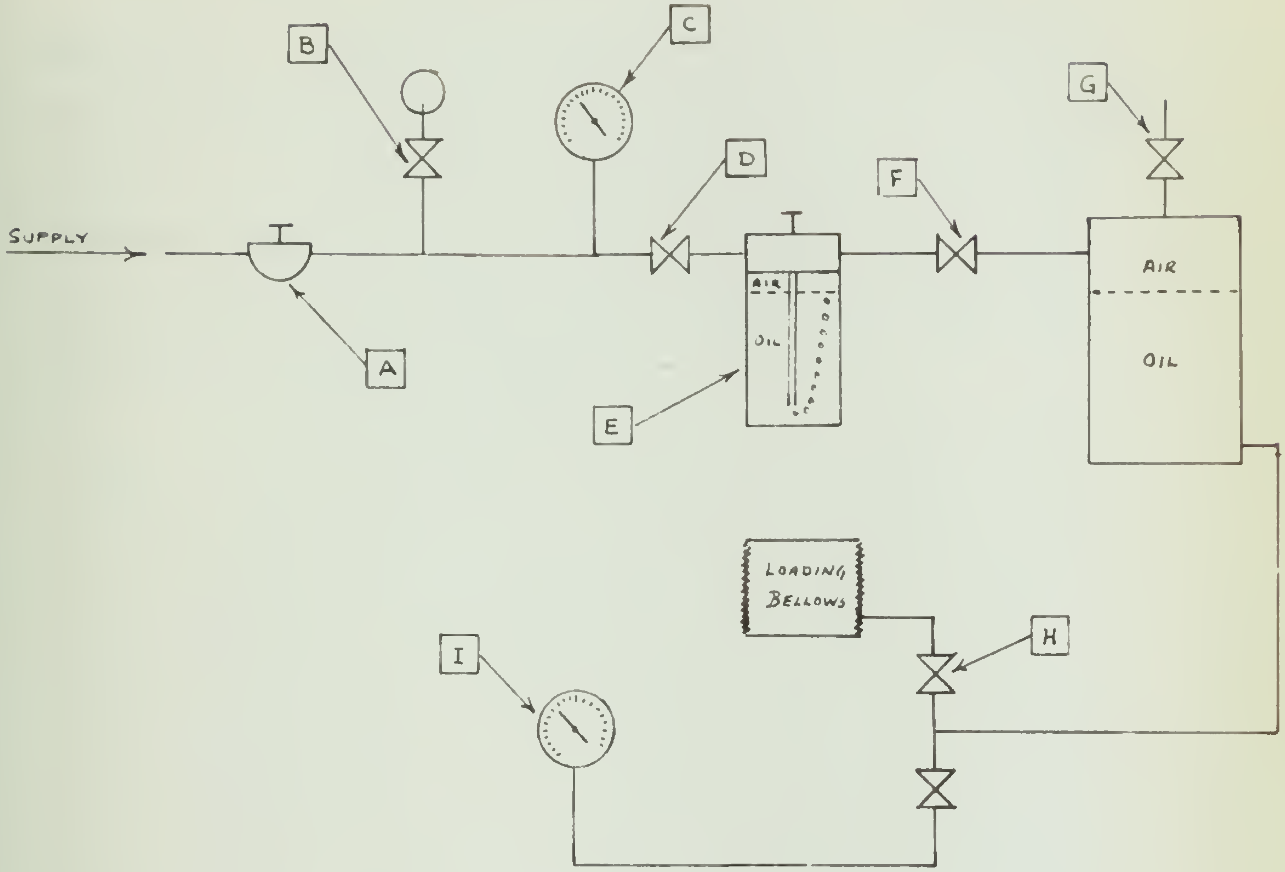
CALIBRATION of TIME - DEPENDENT LOADING DEVICE

LOAD RANGE	DRIVE PRESSURE	PRESSURE ON SAMPLE	BUBBLES / MIN	TIME (MIN)
0 - .75 psi		0 - 1/4 TSF		
.75 - 1.5 psi	7.5 psi	1/4 - 1/2 TSF	5	480
1.5 - 3.0 psi	8 psi	1/2 - 1 TSF	7	480
3.0 - 6.0 psi	20 psi	1 - 2 TSF	15	480
6.0 - 12.0 psi	20 psi	2 - 4 TSF	24	480
12.0 - 24.0 psi	30 psi	4 - 8 TSF	36	480

N.B. THE ABOVE CALIBRATION IS SUBJECT TO ERROR IN THAT THE VARIABLES INVOLVED ARE NOT AMENABLE TO RIGID CONTROL. THE CALIBRATION WAS CONDUCTED WITH NO SAMPLE IN PLACE AND WITH VARYING AIR TEMPERATURES. THE EXTREME VARIANCE OF TIME OF PRESSURE APPLICATION FROM THE ABOVE VALUES MAY BE NOTED IN THE RAW DATA FOR TESTS No 2 and 3. THE PRECISION OF SETTING THE BUBBLE RATE IS OF NECESSITY SUBJECT TO HUMAN APPROXIMATION, AND IS CONSIDERED TO BE THE MAJOR SOURCE OF VARIANCE.

A PROCEDURE FOR APPLICATION OF TIME DEPENDENT LOADING

SCHEMATIC



PROCEDURE

1. CLOSE H
2. CLOSE D
3. ADJUST A TO DESIRED INITIAL PRESSURE
4. ADJUST B UNTIL C READS EXACT INITIAL PRESSURE REQUIRED
5. OPEN D
6. ADJUST E TO TIME-RATE REQUIRED
7. ADJUST G TO INSURE THAT READING ON I IS THE SAME AS AT THE END OF PREVIOUS LOADING CYCLE
8. CHECK E TO INSURE THAT TIME-RATE IS AS REQUIRED
9. QUICKLY CLOSE G
10. QUICKLY OPEN H
11. READ CONSOLIDOMETER AT REQUIRED TIME INTERVALS

FIG. 14

D. Pseudo Time Dependent Loading Tests

Tests 4 ~~and 5~~ were conducted in an effort to approximate time-dependent application of load by use of small incremental loadings over small finite time intervals. Load was applied instantaneously by by-passing the time dependent loading device as shown in Figure 11. Raw data showing pressure increments and loading cycle times are contained in Appendix 4 ~~and 5~~.

E. Permeability Measurements

Direct measurement of Permeability was achieved by means of a constant head permeater as shown in Figure 9. A capillary tube was calibrated to .1 c.c. and volume decrease noted at each reading of the consolidometer. Thus a direct relationship between permeability and void ratio was established for all points of the consolidation process.

Considerable difficulty was experienced in establishing valid permeability data under small loading conditions (i.e. $\frac{1}{4}$ t.s.f.). The permeameter head is sufficient to cause sample uplift prior to application of load and as is shown in Appendix 4, affects the consolidation process to a considerable extent. It was therefore necessary to restrict permeability measurements to loadings of greater than $\frac{1}{2}$ t.s.f.

It must also be noted that the direct measurement of k for such a material as Kaolinite involves extremely small measurements of flow volume. Such measurement is feasible under time-dependent loading conditions since the porosity is decreasing at a rate which permits accurate gage readings for flow volumes of sufficient magnitude as will minimize interpolation errors. However in instantaneously loaded samples, the load application:

(1) Creates an initial surge of pressure which causes a negative flow into permeameter for a period of approximately 3 minutes.

(2) Seriously restricts the evaluation of permeability data after the initial 3 minute surge period, because of the lack of knowledge as to the time or pressure limits of its influence after the initial 3 minutes.

The problem involved in (2) above is reflected in widely scattered permeability values for all load increments of Test No. 1.

PART V,

RESULTS and DISCUSSION

A. EQUIPMENT

The test equipment, as designed and assembled, provided data of sufficient accuracy for a pilot study of this nature. For future development of test data, requiring reproducible results for purposes of definitive analysis and for publication, the equipment should be modified to provide the following:

(1) Precise control of load application during the Time Dependent Loading cycles.

(2) Smaller bore, equivilent volume permeameter to provide more precise calibration of flow volume.

DISCUSSION:

(1) The application of Load at a fixed linear rate is of extreme importance in the conduct of tests designed to investigate the validity of Schiffman's extension of the theory for the one dimensional flow condition. It is noted that the rate of change of imposed excess pore pressure, R, found in the governing differential equation, is in fact the rate of application of load. Therefore for any of the cases considered in his treatment of the one-dimensional flow condition, the loading device must be capable of precise control, if correlative data is to be developed.

(2) The use of the Constant-Head Permeameter is well adapted for precise measurement of permeability during the consolidation process. However, the small flow volume, encountered with the use of clay soils, dictates a finer calibration of the horizontal tube, in order to minimize approximating errors. A smaller bore tube would provide the precision required but has the disadvantage of reduced volume availability. Such reduction in volume can only be compensated for in two ways: (1) Extreme length of tube or (2) Constant attendance to preclude evacuation of the tube. A reasonable balancing of these two factors would appear to be feasible. The increase in accuracy, resultant, cannot be estimated, but would be of extreme value in analyzing permeability variation.

B. TEST NO.1 - STANDARD CONSOLIDATION TEST

Test Data in graphical form is presented in Figure 16.

Discussion:

The data developed is typical of the "type" curves for the Kaolin clay used. The work of previous investigators (10) closely parallels the results achieved. The variance in C_v values is reasonable and the shape of curves is similar.

The problem of sample uplift, due to the head of the permeameter, precludes permeability measurements prior to the application of $\frac{1}{2}$ ton per square foot loading. This, however, is not a serious difficulty since it should be noted that the loading range involved is usually on the precompression portion of the e-log P curve. Since usable data can be developed only on the straight-line portion of the curve, where the uplift problem is no longer existant, the problem does not actually affect test results.

The determination of the permeability of the test samples, under instantaneous load application, is a problem which requires a great deal of interpretative analysis during the primary consolidation period. It is noted that an initial negative flow into the permeameter persists for a period of 2-3 minutes, immediately following the application of load. This flow can be interpreted in three ways:

(1) That the flow is due to the squeezing out of Pore water by the application of load, which process is essentially complete during the primary consolidation period. With the dissipation of such pore water, the head of the permeameter then induces a positive flow. The validity of the initial positive flow measurements is subject to serious question since there is still existant a varying amount of hydrostatic excess.

(2) That the flow is due to a hydraulic balancing of the load-imposed pore pressure and the permeameter head. Such balancing is subject to a time lag since the transmissibility of pore pressure differs at the top and bottom boundaries due to the counterhead of the permeameter.

(3) A combination of (1) and (2) above.

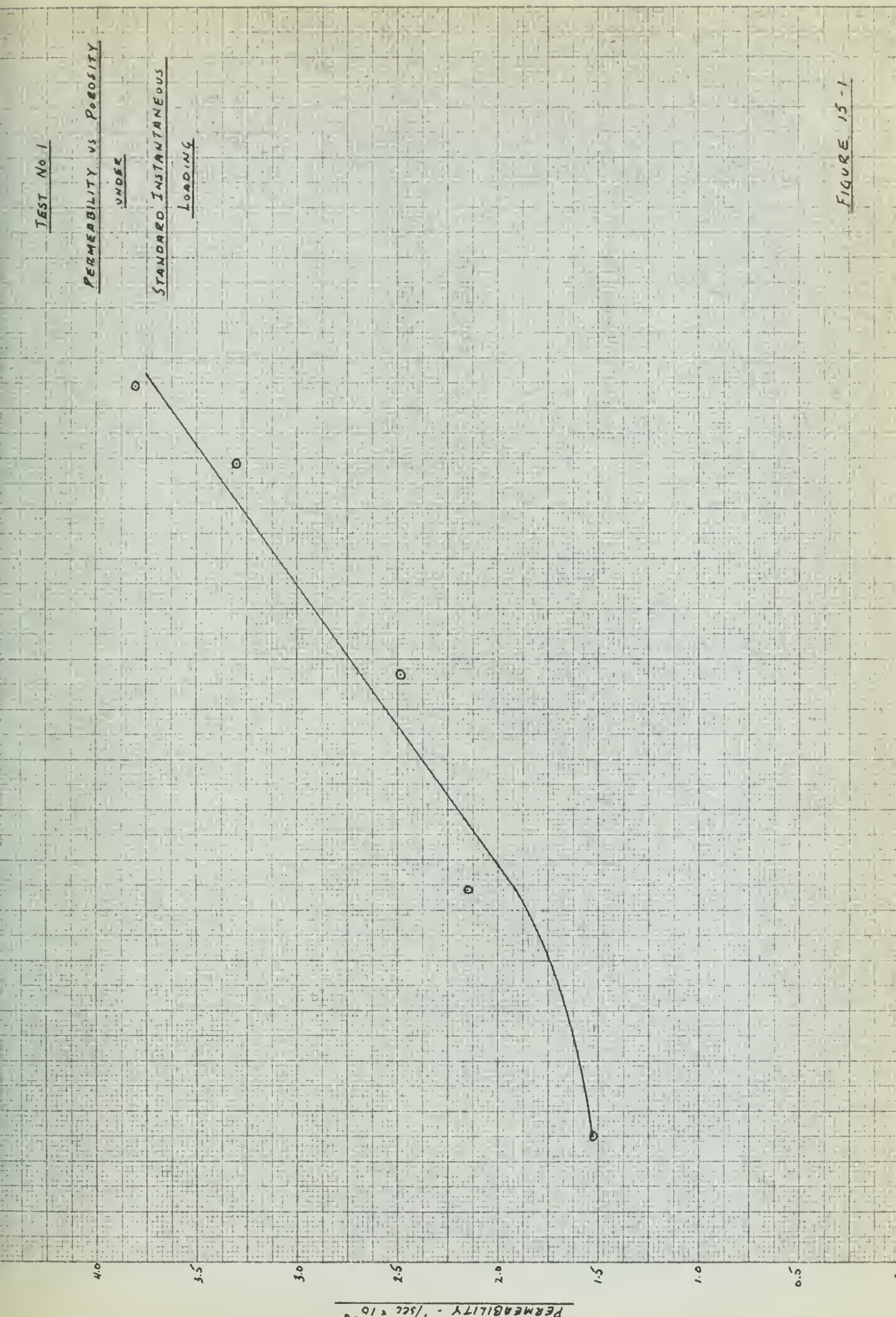

TEST No. 1
PERMEABILITY vs POROSITY
UNDER
STANDARD INSTANTANEOUS
LOADING
POROSITY - n
PERMEABILITY - 1/sec × 10^-6
.38
.39
.40
.41
.42
.43
.44
.45
.46
.47
.48
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

FIGURE 15-1

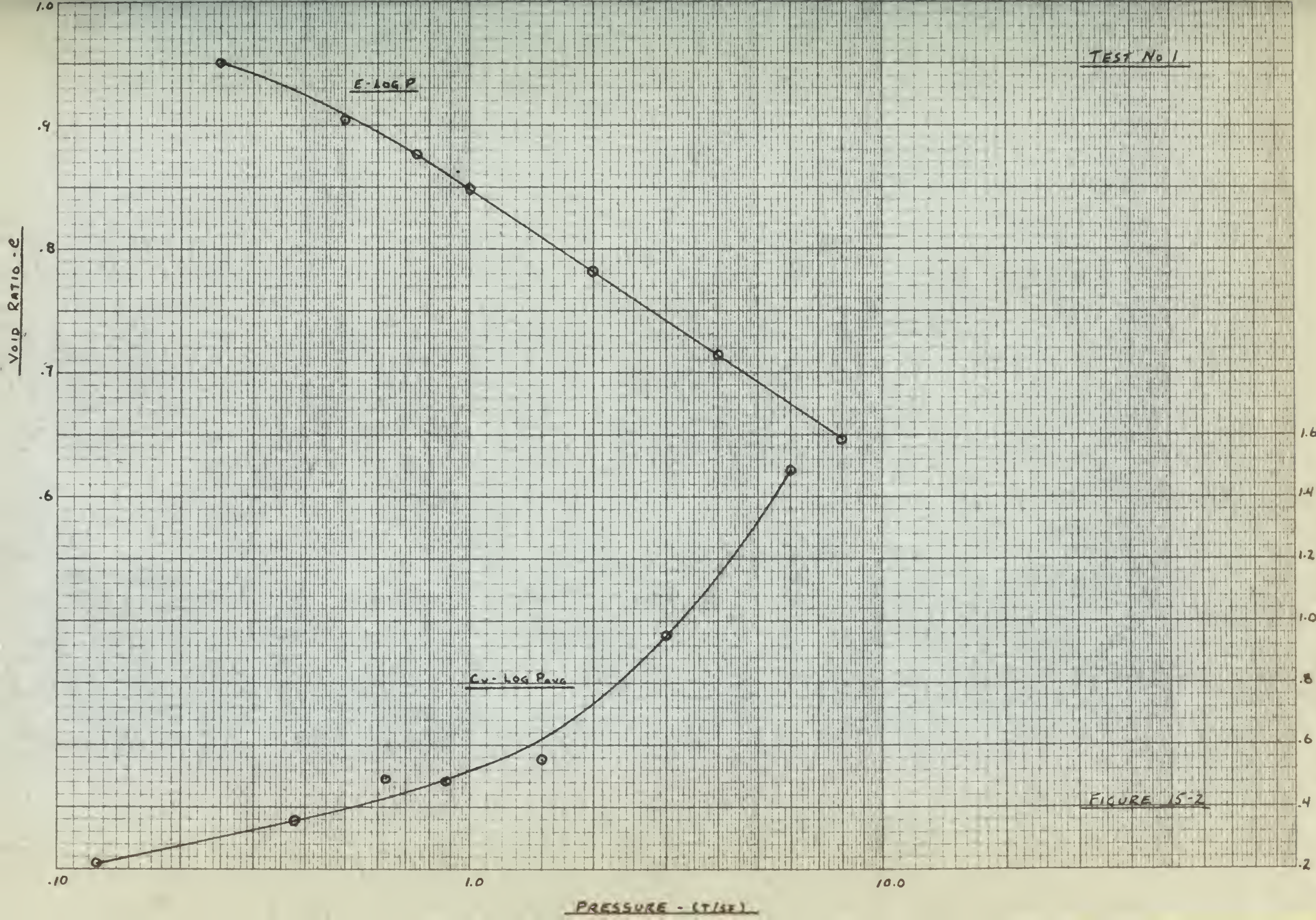

TEST No 1
E-LOG P
Cv-LOG Pavg
VOID RATIO - e
COEFFICIENT OF CONSOLIDATION - Cv
PRESSURE - (T/SF)
1.0
.9
.8
.7
.6
1.6
1.4
1.2
1.0
.8
.6
.4
.2
.10
1.0
10.0

FIGURE 15-2

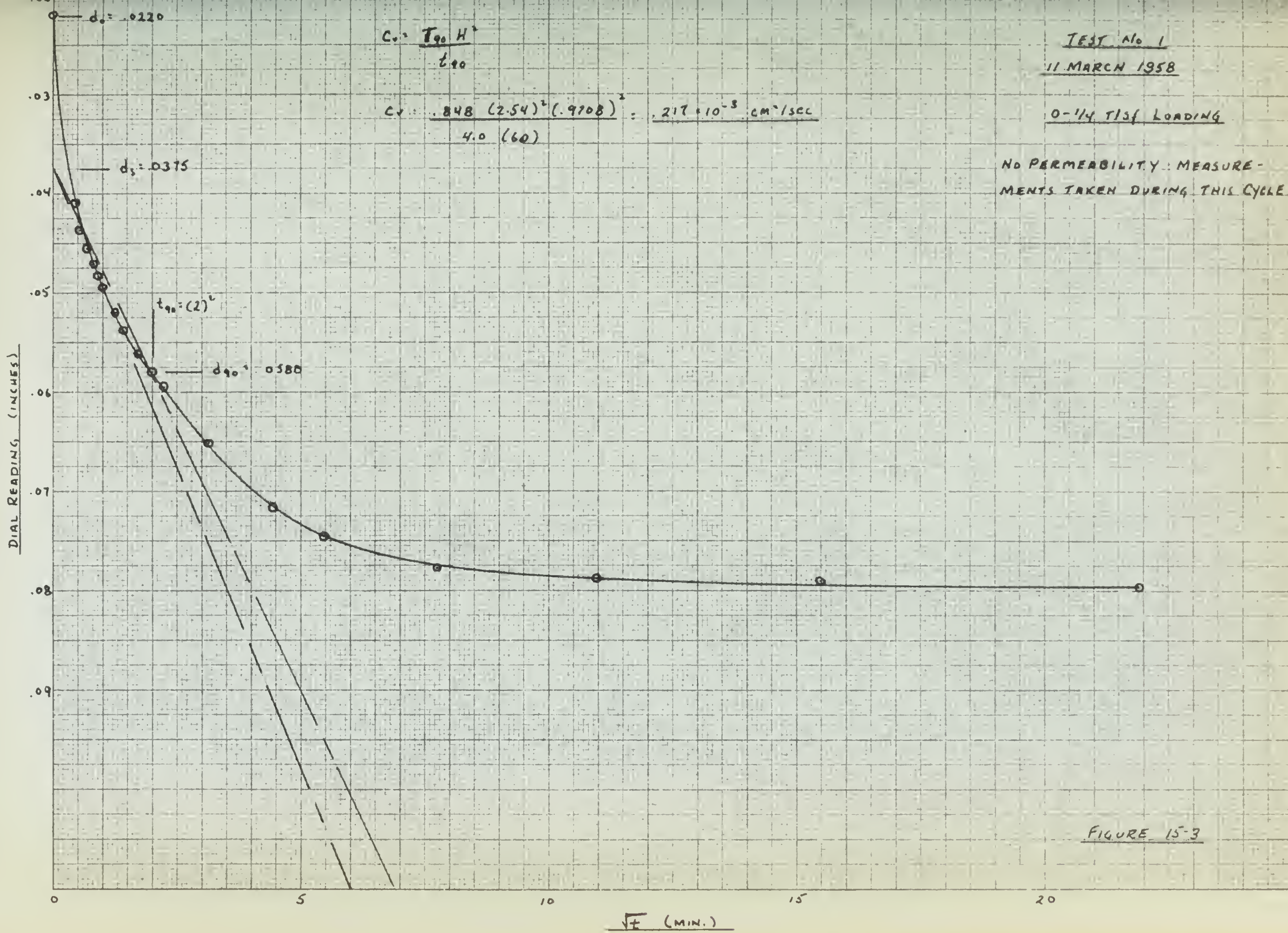

d_0 = .0220
d_s = .0375
t_{90} = $(2)^2$
d_{90} = .0580
$C_v = \frac{T_{90} H^2}{t_{90}}$
$C_v = \frac{.848\ (2.54)^2 (.9708)^2}{4.0\ (60)} = .217 \times 10^{-3}$ cm²/sec
TEST No 1
11 MARCH 1958
0-1/4 T/sf LOADING
NO PERMEABILITY MEASUREMENTS TAKEN DURING THIS CYCLE
DIAL READING (INCHES)
.03
.04
.05
.06
.07
.08
.09
0
5
10
15
20
$\sqrt{t}$ (MIN.)

FIGURE 15-3

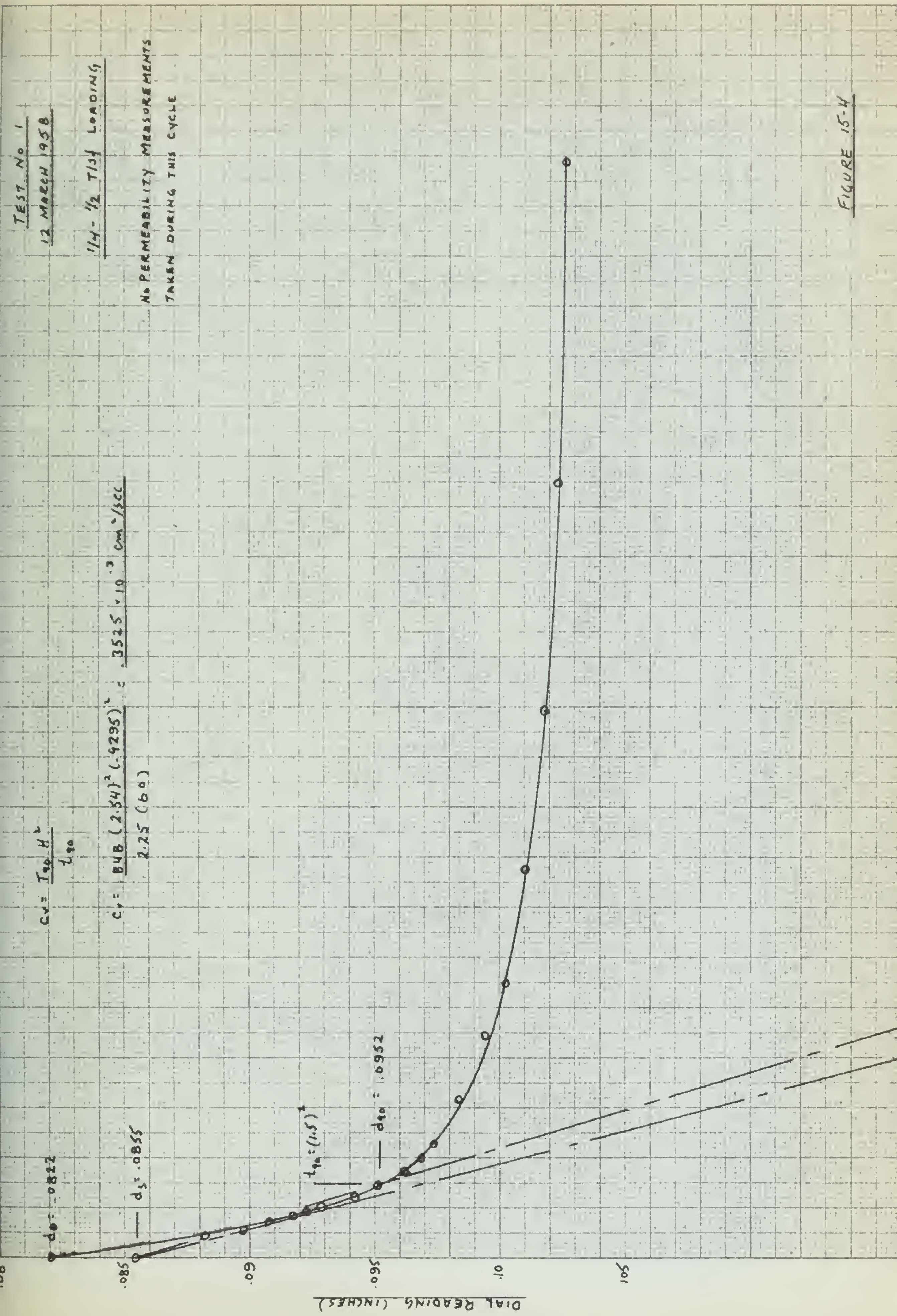

TEST No 1
12 MARCH 1958
1/4 - 1/2 T/SQ LOADING
NO PERMEABILITY MEASUREMENTS TAKEN DURING THIS CYCLE
$C_V = \frac{T_{90} H^2}{t_{90}}$
$C_V = \frac{.848 (2.54)^2 (.4295)^2}{2.25 (60)} = .3525 \times 10^{-3}$ cm²/sec
$d_0 = .0822$
$d_s = .0855$
$t_{90} = (1.5)^2$
$d_{90} = .0952$
.085
.09
.095
.10
.105
DIAL READING (INCHES)
0
5
10
15
20
$\sqrt{t}$ (MIN.)

FIGURE 15-4

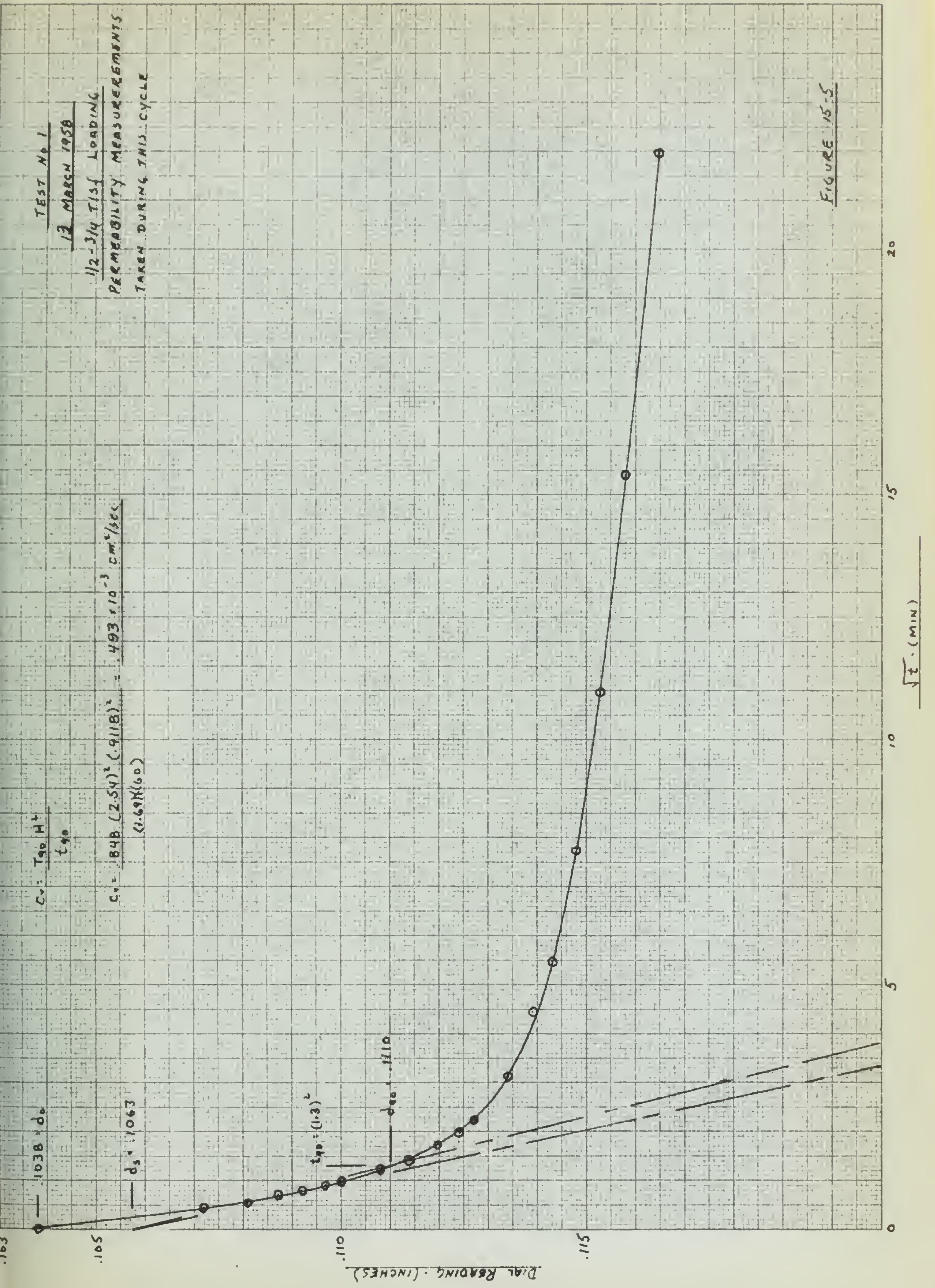
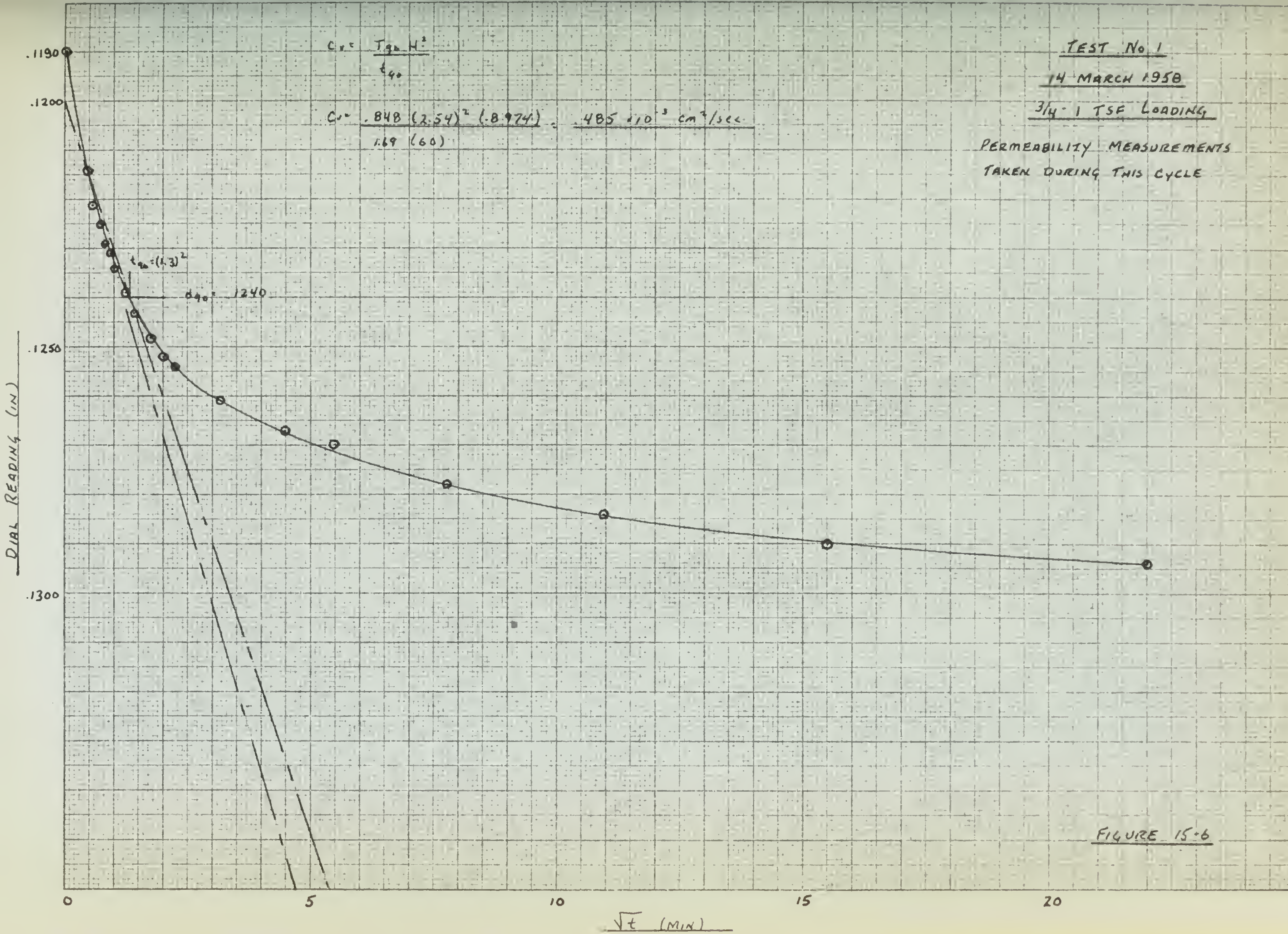

TEST No 1
13 MARCH 1958
1/2-3/4 T/SF LOADING
PERMEABILITY MEASUREMENTS
TAKEN DURING THIS CYCLE
Cv = T90 H² / t90
Cv = .848 (2.54)² (.9118)² / (1.69)(60) = 493 × 10⁻³ cm²/sec
.1038 = d0
ds = .1063
t90 = (1.3)²
d90 = .1110
.105
.110
.115
DIAL READING - (INCHES)
0
5
10
15
20
√t - (MIN)

FIGURE 15-5



$C_v = \frac{T_{90} H^2}{t_{90}}$
$C_v = \frac{.848 (2.54)^2 (.8974)}{1.69 (60)} = .485 \times 10^{-3}\ cm^2/sec$
TEST No 1
14 MARCH 1958
3/4 - 1 TSF LOADING
PERMEABILITY MEASUREMENTS TAKEN DURING THIS CYCLE
$t_{90} = (1.3)^2$
$d_{90} = .1240$
.1190
.1200
.1250
.1300
DIAL READING (IN)
0
5
10
15
20
$\sqrt{t}$ (MIN)

FIGURE 15-6

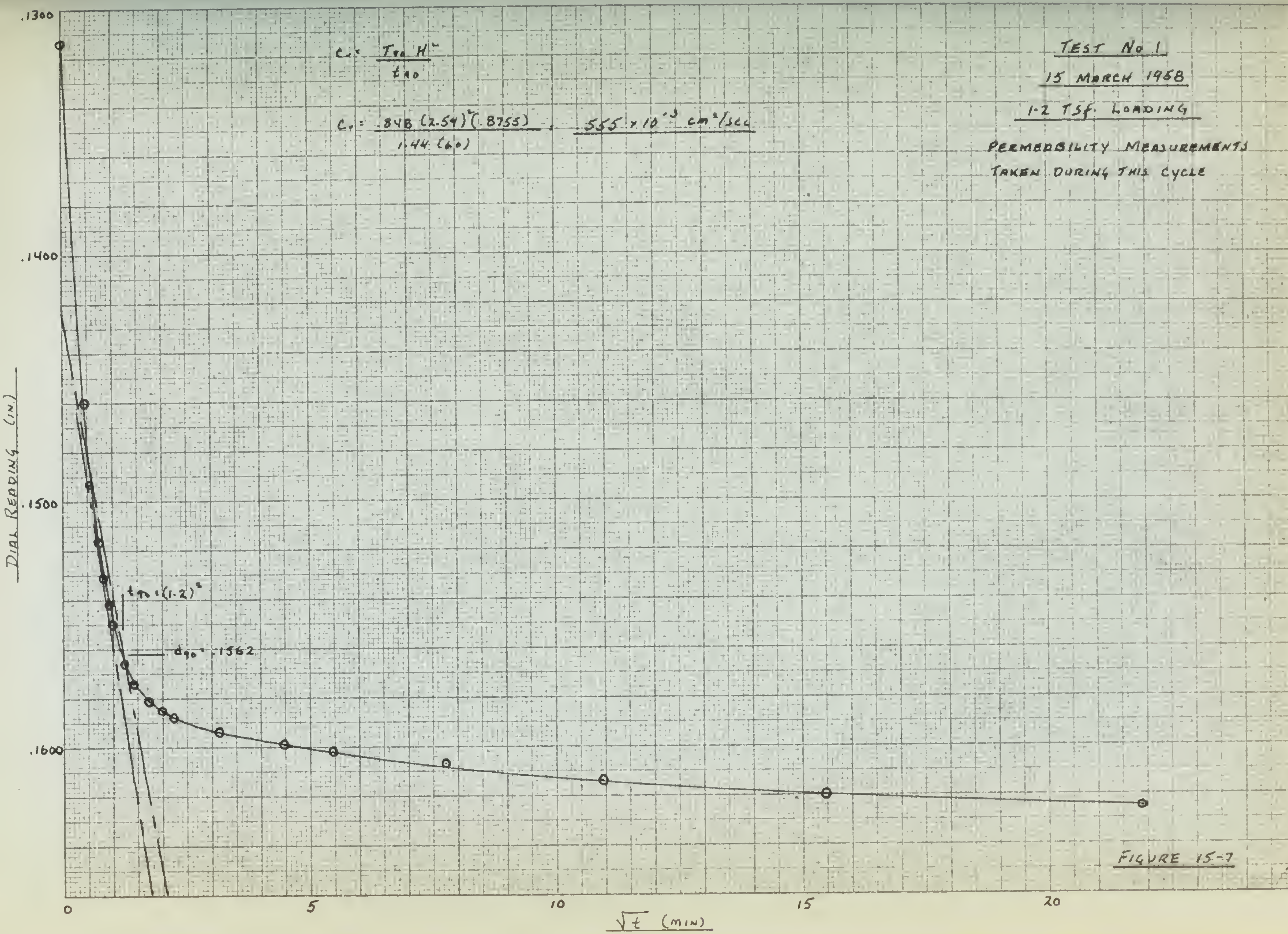

TEST No 1
15 MARCH 1958
1-2 TSf. LOADING
PERMEABILITY MEASUREMENTS
TAKEN DURING THIS CYCLE
$c_v = \frac{T_{90} H^2}{t_{90}}$
$c_v = \frac{.848 (2.54)^2 (.8755)}{1.44 (60)} = .555 \times 10^{-3}$ cm²/sec
$t_{90} = (1.2)^2$
$d_{90} = .1562$
.1300
.1400
.1500
.1600
DIAL READING (IN.)
0
5
10
15
20
$\sqrt{t}$ (MIN)

FIGURE 15-7

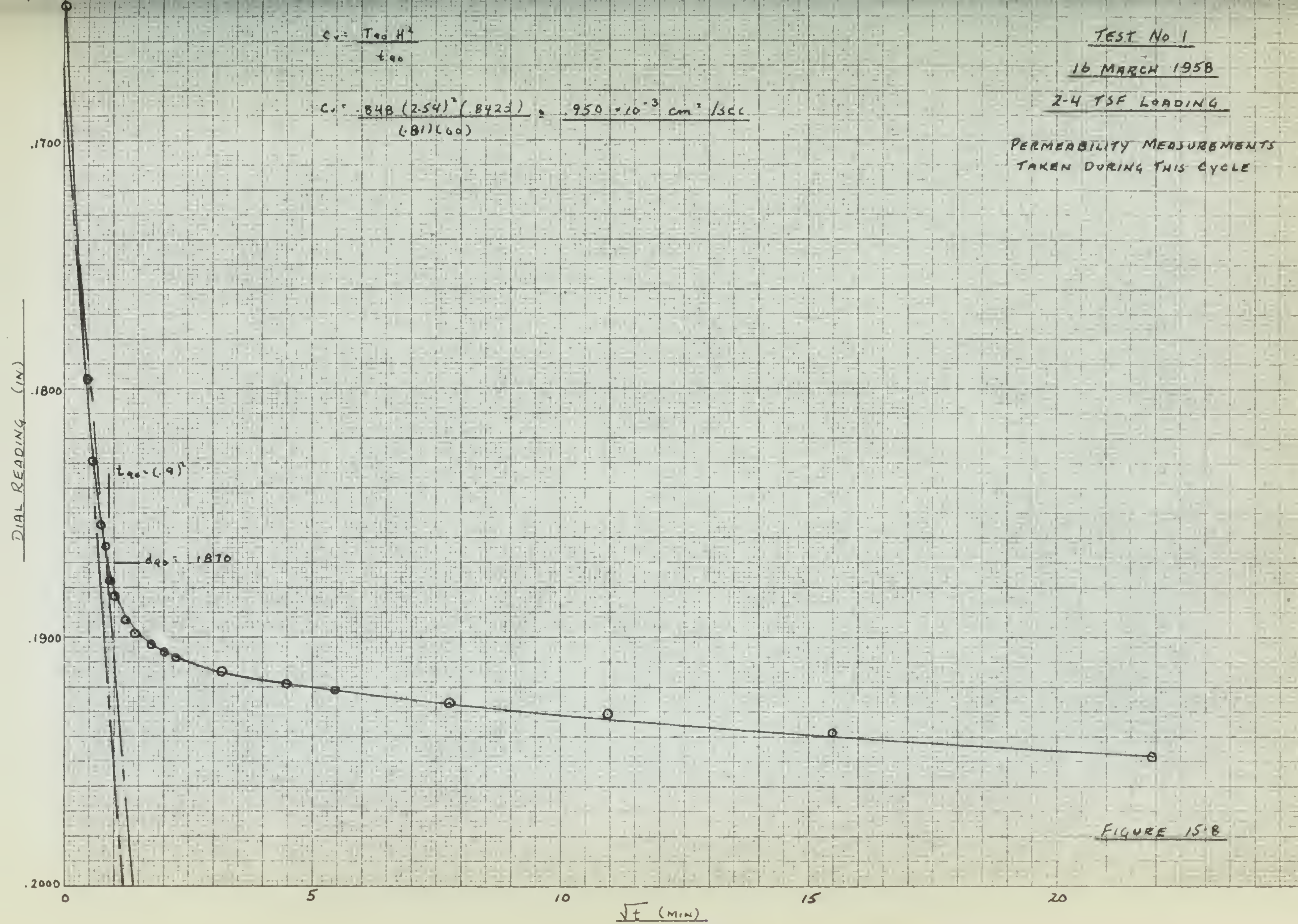

TEST No. 1
16 MARCH 1958
2-4 TSF LOADING
PERMEABILITY MEASUREMENTS
TAKEN DURING THIS CYCLE
$c_v = \frac{T_{90} H^2}{t_{90}}$
$c_v = \frac{.848 (2.54)^2 (.8423)}{(.81)(60)} = .950 \times 10^{-3}$ cm²/sec
$t_{90} = (.9)^2$
$d_{90} = .1870$
DIAL READING (IN)
.1700
.1800
.1900
.2000
0
5
10
15
20
$\sqrt{t}$ (MIN)

FIGURE 15.8

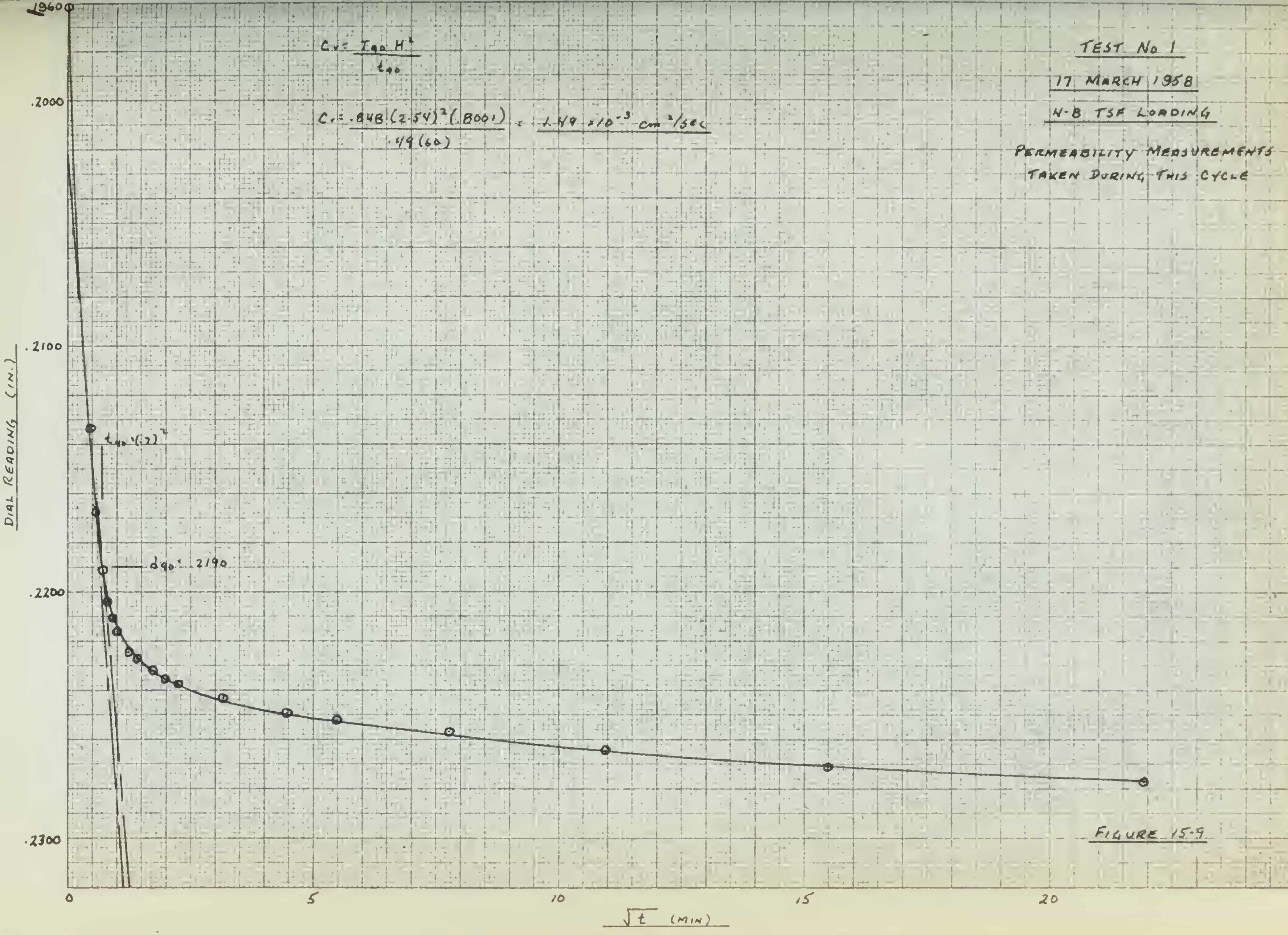

TEST No 1
17 MARCH 1958
4-8 TSF LOADING
PERMEABILITY MEASUREMENTS
TAKEN DURING THIS CYCLE
$C_v = \frac{T_{90} H^2}{t_{90}}$
$C_v = \frac{.848 (2.54)^2 (.8001)}{.49 (60)} = 1.49 \times 10^{-3}\ cm^2/sec$
$t_{90} = (.7)^2$
$d_{90} = .2190$
DIAL READING (IN.)
.1960
.2000
.2100
.2200
.2300
$\sqrt{t}$ (MIN)
0
5
10
15
20

FIGURE 15-9

C. TESTS NO. 2 and 3 - TIME DEPENDENT LOADING

Test Data in graphical form is presented in Figure 17.

DISCUSSION:

The rate of application of load in the majority of increments was such that the consolidation process was essentially concurrent with load application. The curves developed show the same shape and range of variation for each test.

The increase in the permeability of the sample, in the later stages of the consolidation process, is a phenomenon which appears to offer a subject for future study. This increase is not predictable, nor is it always present. It would appear that, at some stage of the plastic range, there is an internal adjustment of pore-channel "effective" areas, which causes scattered increases and decreases in the permeability. The effect is such that it has been termed the "yo-yo effect". The only reasonable hypotheses proposed at the present time are:

(1) That dissolved gases in the permeant (ie. water in these tests) are condensing and providing an increase in flow volume, which is measurable on the permeameter.

(2) That the ionically bound water "hull" which restricts the flow of the permeant during the primary

consolidation period, is, by pressure adjustment, being sheared from the clay particles, thus increasing flow by the volume of the sheared hull and the increased volume of flow thru the enlarged pore-channel. Decrease in flow could be the result of structural re-arrangement, due to particles shifting, in response to the pressure void left by the shearing of the compressed water hull. The increased stress on the particles, which would cause such shifting, is available from the dissipation of the structural pseudo-hydrostatic-excess pressure of the water hull.

(3) That errors in guage readings have occured. Due to the cumulative type readings taken, and the repetition of this effect, it is considered that errors due to (3) above are minimal.

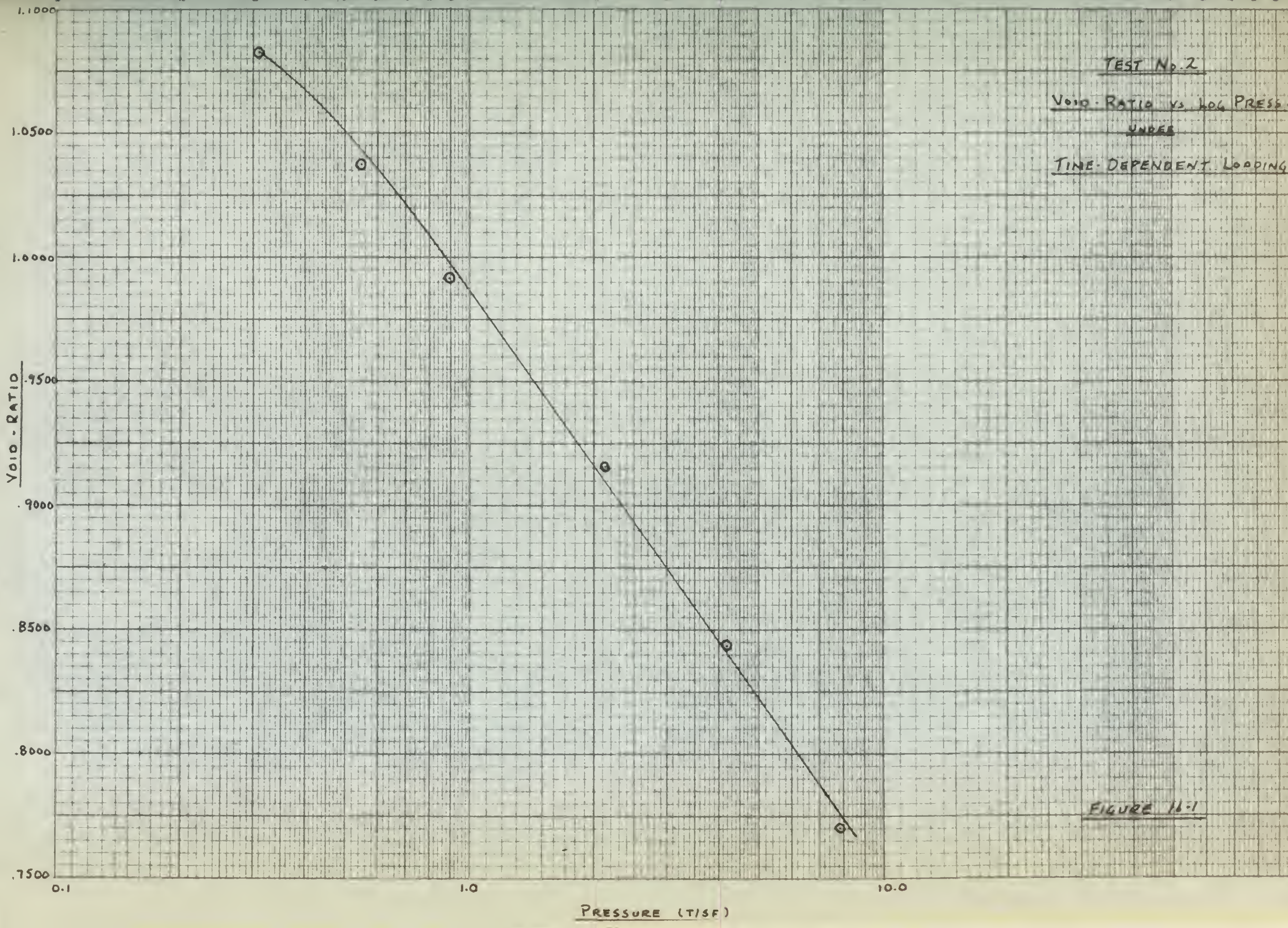

TEST No. 2
VOID-RATIO VS. LOG PRESS.
UNDER
TIME-DEPENDENT LOADING
1.1000
1.0500
1.0000
.9500
.9000
.8500
.8000
.7500
VOID-RATIO
0.1
1.0
10.0
PRESSURE (T/SF)

FIGURE 11-1

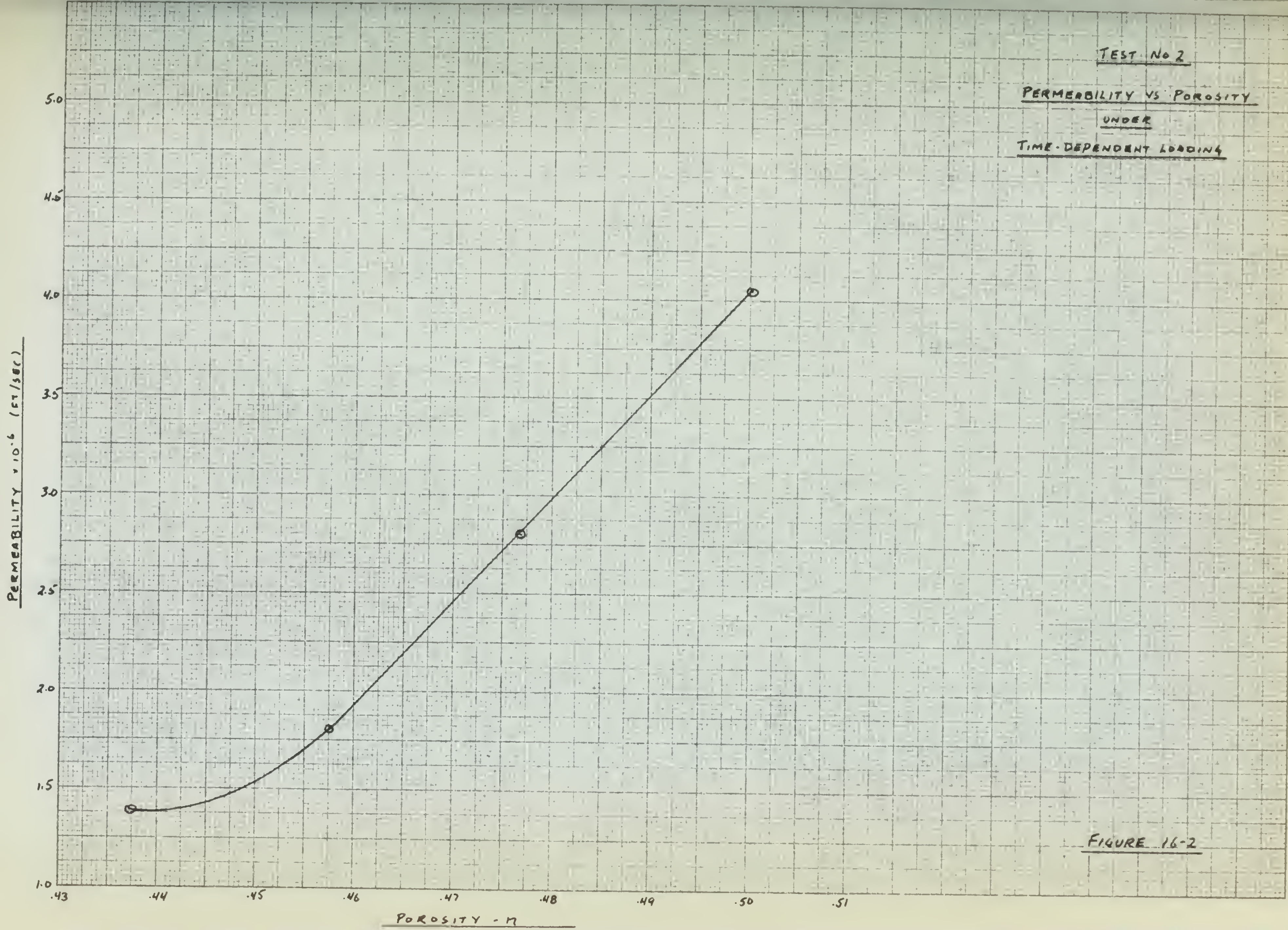

TEST No 2
PERMEABILITY VS POROSITY
UNDER
TIME-DEPENDENT LOADING
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
PERMEABILITY × 10^-6 (FT/SEC)
.43
.44
.45
.46
.47
.48
.49
.50
.51
POROSITY - n

FIGURE 16-2

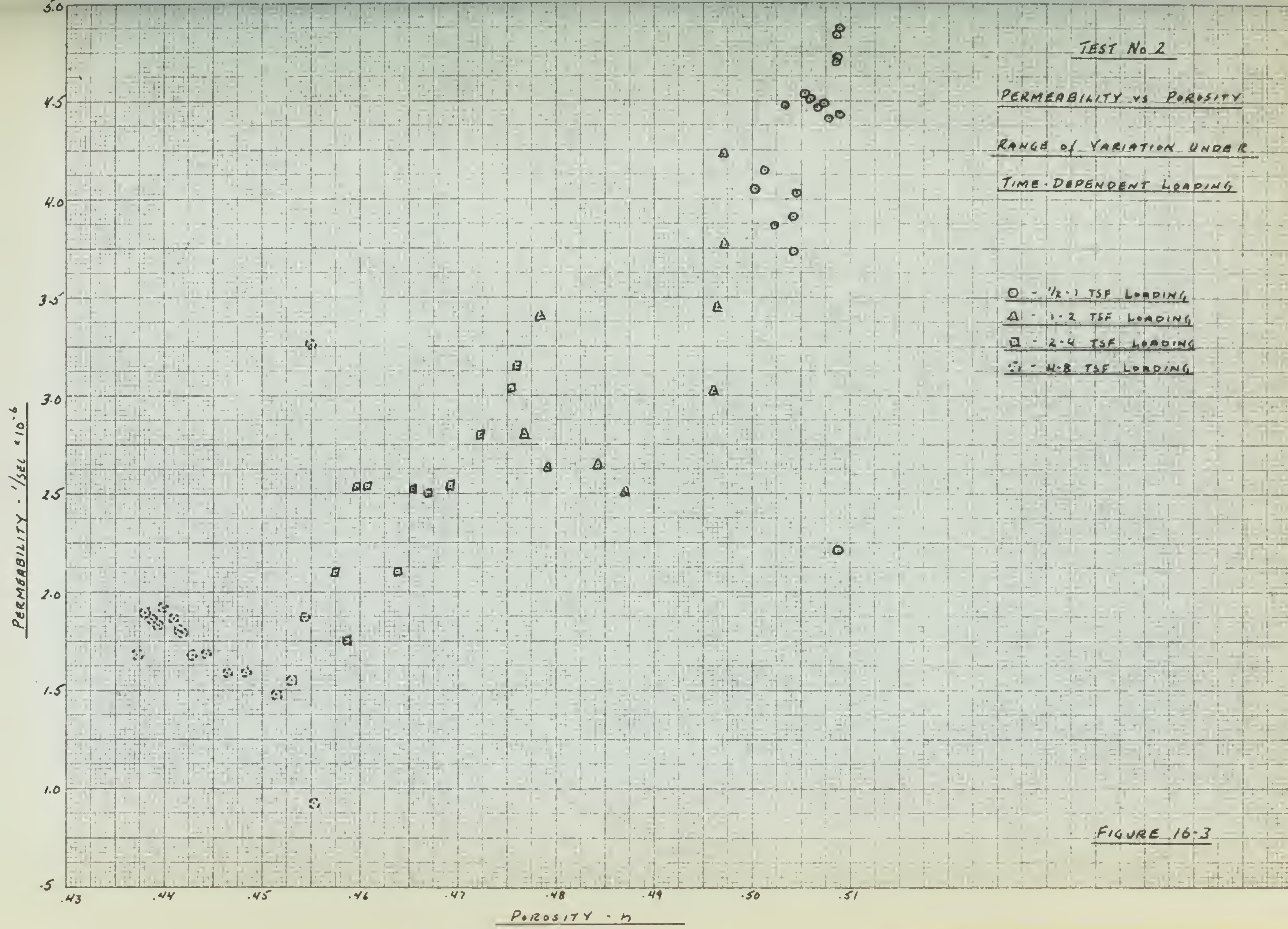

TEST No 2
PERMEABILITY vs POROSITY
RANGE of VARIATION UNDER
TIME-DEPENDENT LOADING
⊙ - 1/2-1 TSF LOADING
Δ - 1-2 TSF LOADING
⊡ - 2-4 TSF LOADING
⁘ - 4-8 TSF LOADING
PERMEABILITY - 1/sec ×10⁻⁶
POROSITY - n
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
.43
.44
.45
.46
.47
.48
.49
.50
.51

FIGURE 16-3

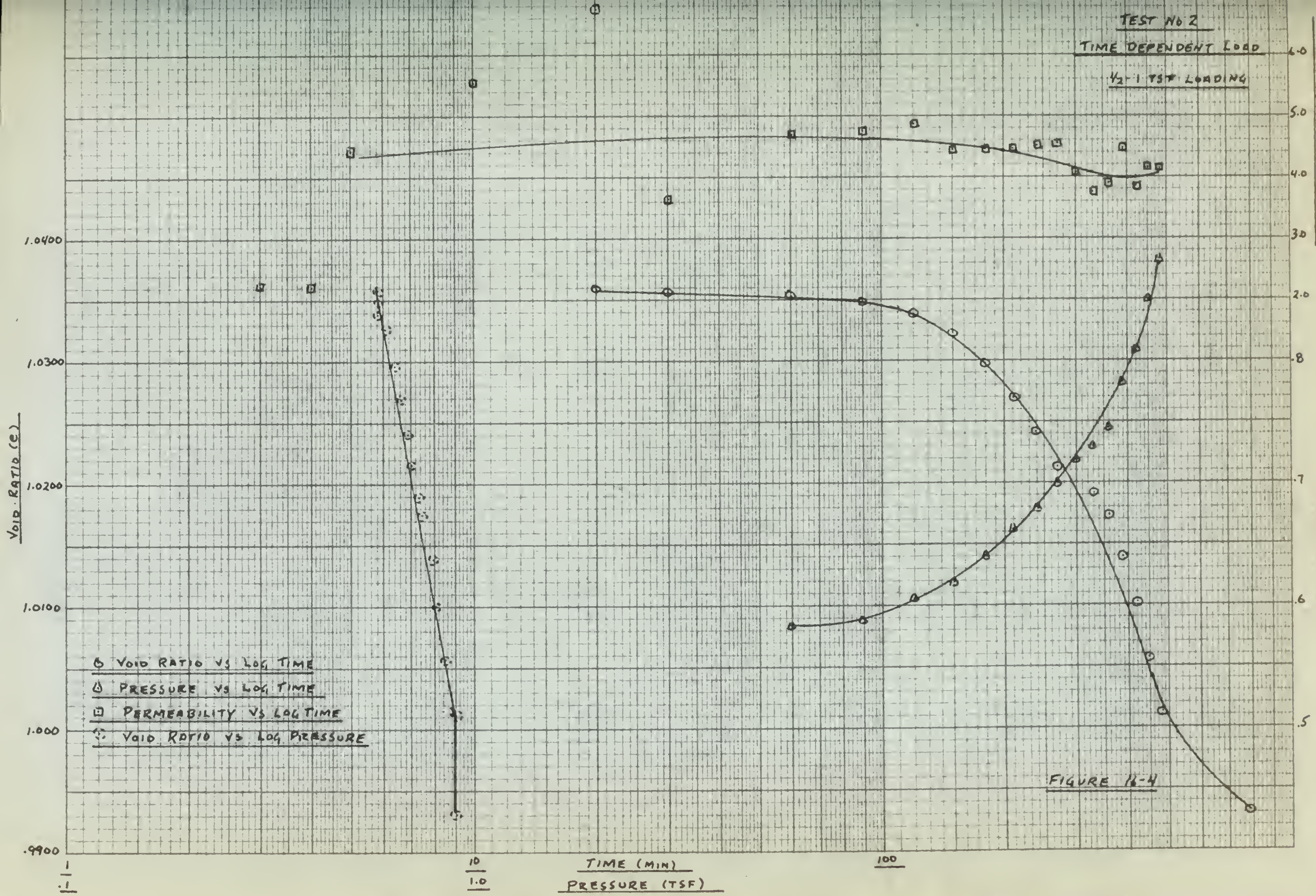

TEST No 2
TIME DEPENDENT LOAD
1/2 - 1 TSF LOADING
PERMEABILITY · 10^-6 (1/SEC)
6.0
5.0
4.0
3.0
2.0
.8
.7
.6
.5
PRESSURE (TSF)
VOID RATIO (e)
1.0400
1.0300
1.0200
1.0100
1.000
.9900
1
.1
10
1.0
100
TIME (MIN)
PRESSURE (TSF)
VOID RATIO VS LOG TIME
PRESSURE VS LOG TIME
PERMEABILITY VS LOG TIME
VOID RATIO VS LOG PRESSURE

FIGURE 16-4

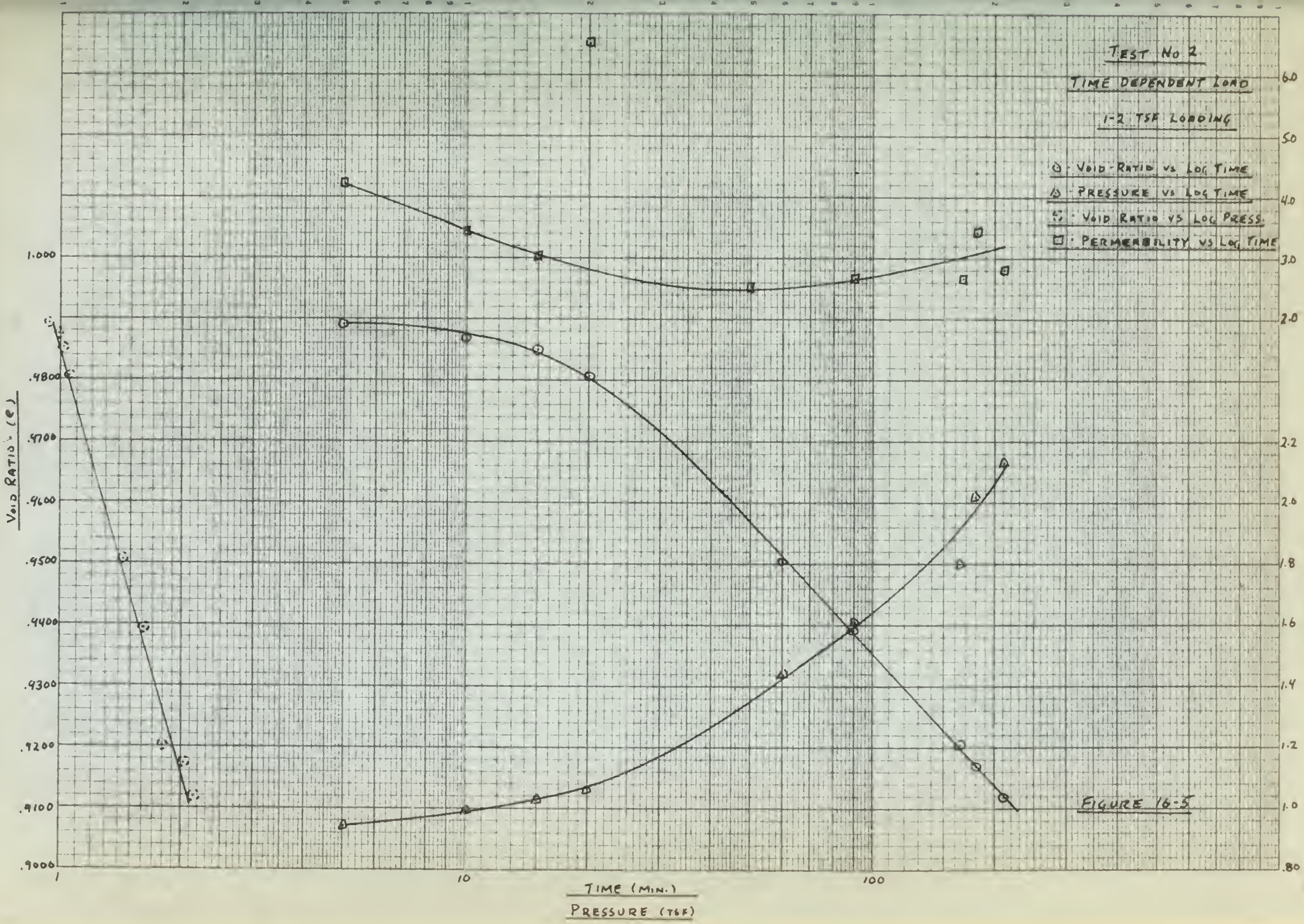
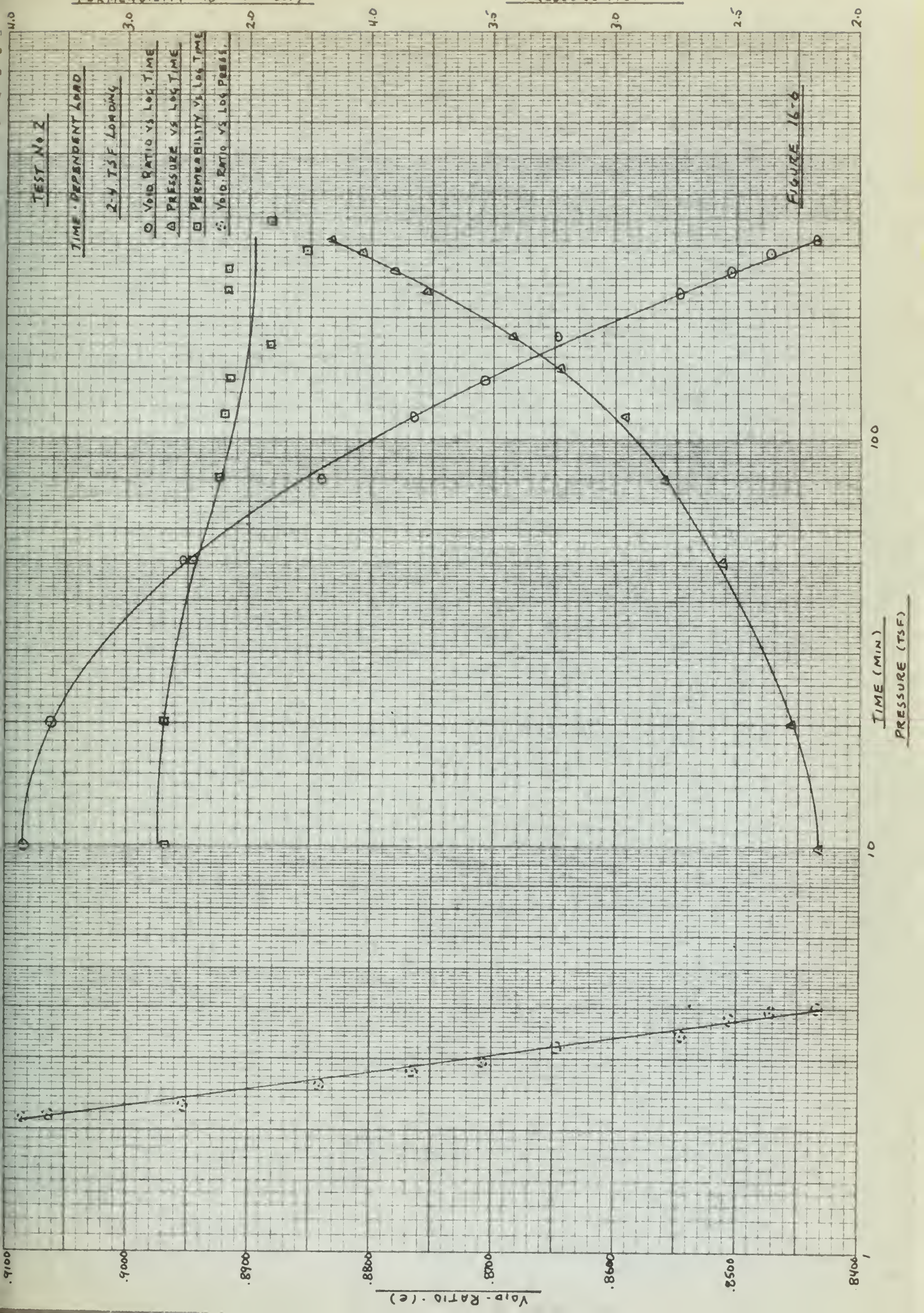
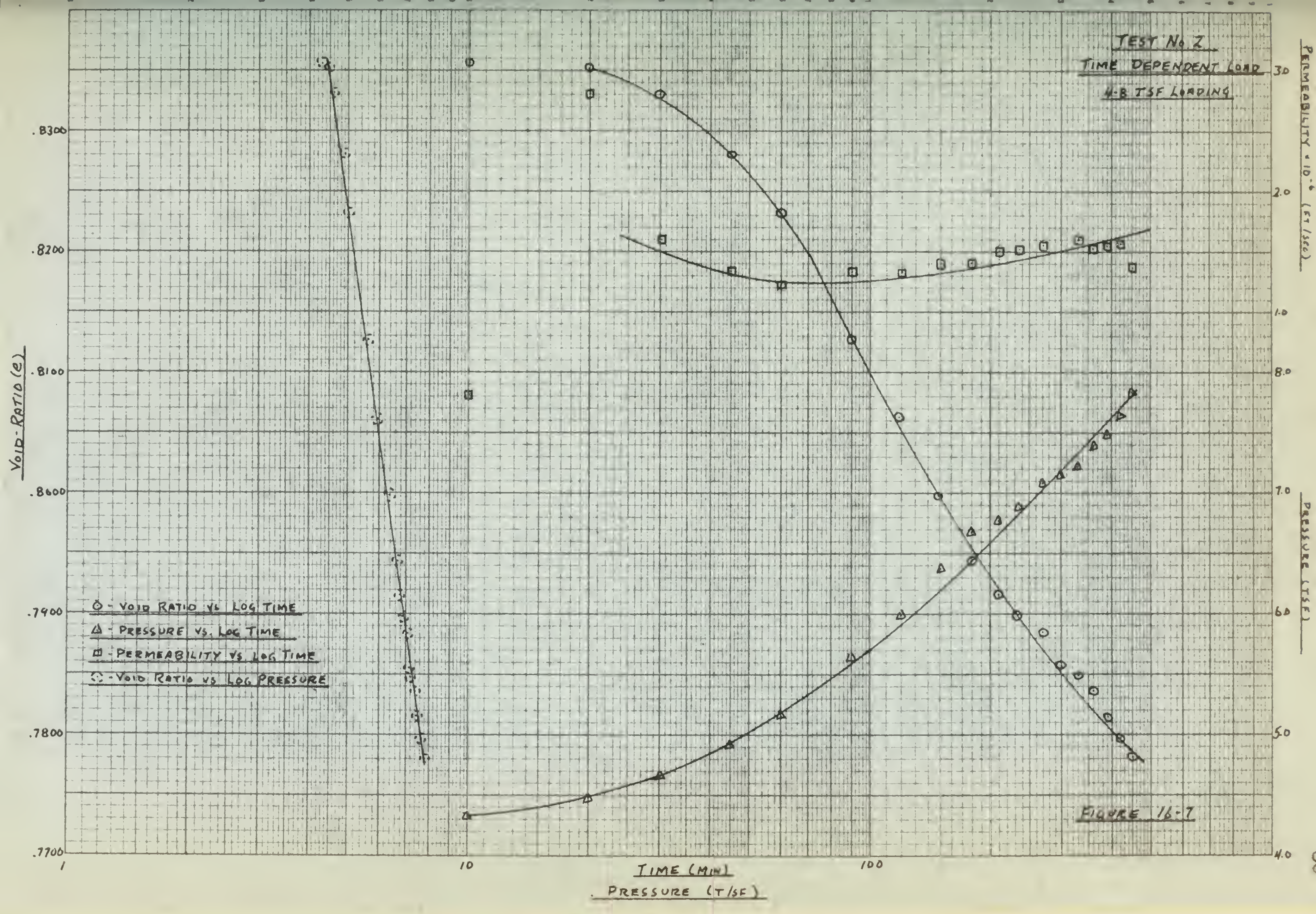

Test No 2
Time Dependent Load
1-2 TSF Loading
⊙ · Void-Ratio vs Log Time
△ · Pressure vs Log Time
⊙ · Void Ratio vs Log Press.
⊡ · Permeability vs Log Time
Void Ratio (e)
1.000
.9800
.9700
.9600
.9500
.9400
.9300
.9200
.9100
.9000
Permeability · 10⁻⁸ (ft/sec)
6.0
5.0
4.0
3.0
2.0
Pressure (TSF)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.80
1
10
100
Time (Min.)
Pressure (TSF)

FIGURE 16-5


PERMEABILITY ·10^-6 (FT/SEC)
PRESSURE (TSF)
TEST No 2
TIME · DEPENDENT LOAD
2-4 TSF LOADING
VOID RATIO VS. LOG TIME
PRESSURE VS. LOG TIME
PERMEABILITY VS LOG TIME
VOID RATIO VS LOG PRESS.
FIGURE 16-6
TIME (MIN)
PRESSURE (TSF)
VOID - RATIO - (e)
4.0
3.0
2.0
4.0
3.5
3.0
2.5
2.0
1
10
100
.9100
.9000
.8900
.8800
.8700
.8600
.8500
.8400


TEST No. 2
TIME DEPENDENT LOAD
4-8 TSF LOADING
VOID-RATIO (e)
.8300
.8200
.8100
.8600
.7900
.7800
.7700
1
10
100
TIME (MIN)
PRESSURE (T/SF)
PERMEABILITY • 10^-6 (FT/SEC)
3.0
2.0
1.0
8.0
7.0
6.0
5.0
4.0
PRESSURE (TSF)
○ - VOID RATIO VS LOG TIME
△ - PRESSURE VS. LOG TIME
□ - PERMEABILITY VS LOG TIME
⁘ - VOID RATIO VS LOG PRESSURE
FIGURE 16-7

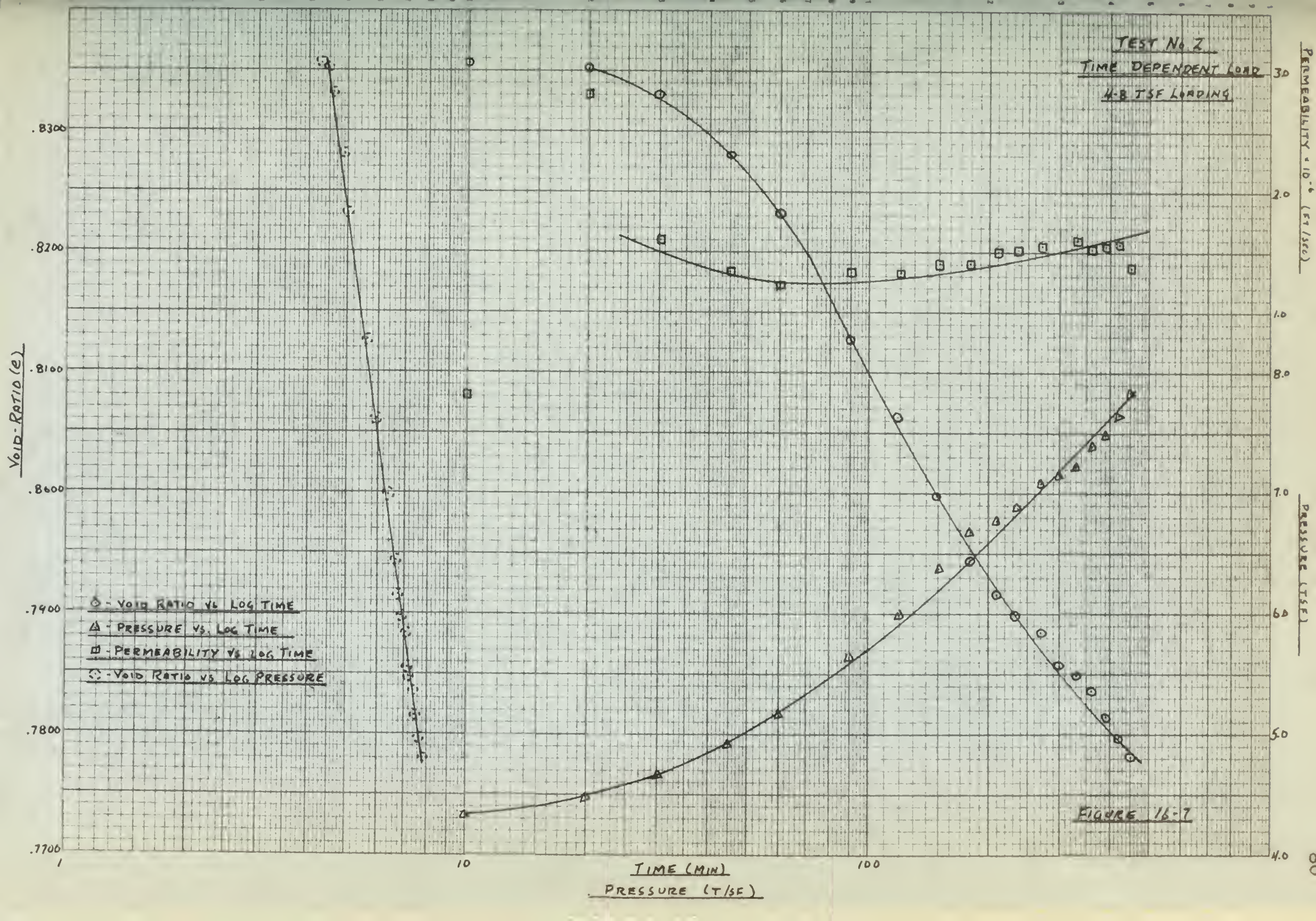

TEST No 2
TIME DEPENDENT LOAD
4.8 TSF LOADING
VOID-RATIO (e)
.8300
.8200
.8100
.8600
.7900
.7800
.7700
1
10
100
TIME (MIN)
PRESSURE (T/SF)
PERMEABILITY × 10^-6 (FT/SEC)
3.0
2.0
1.0
8.0
7.0
6.0
5.0
4.0
PRESSURE (TSF)
- VOID RATIO VS LOG TIME
- PRESSURE VS. LOG TIME
- PERMEABILITY VS LOG TIME
- VOID RATIO VS LOG PRESSURE

FIGURE 16-7

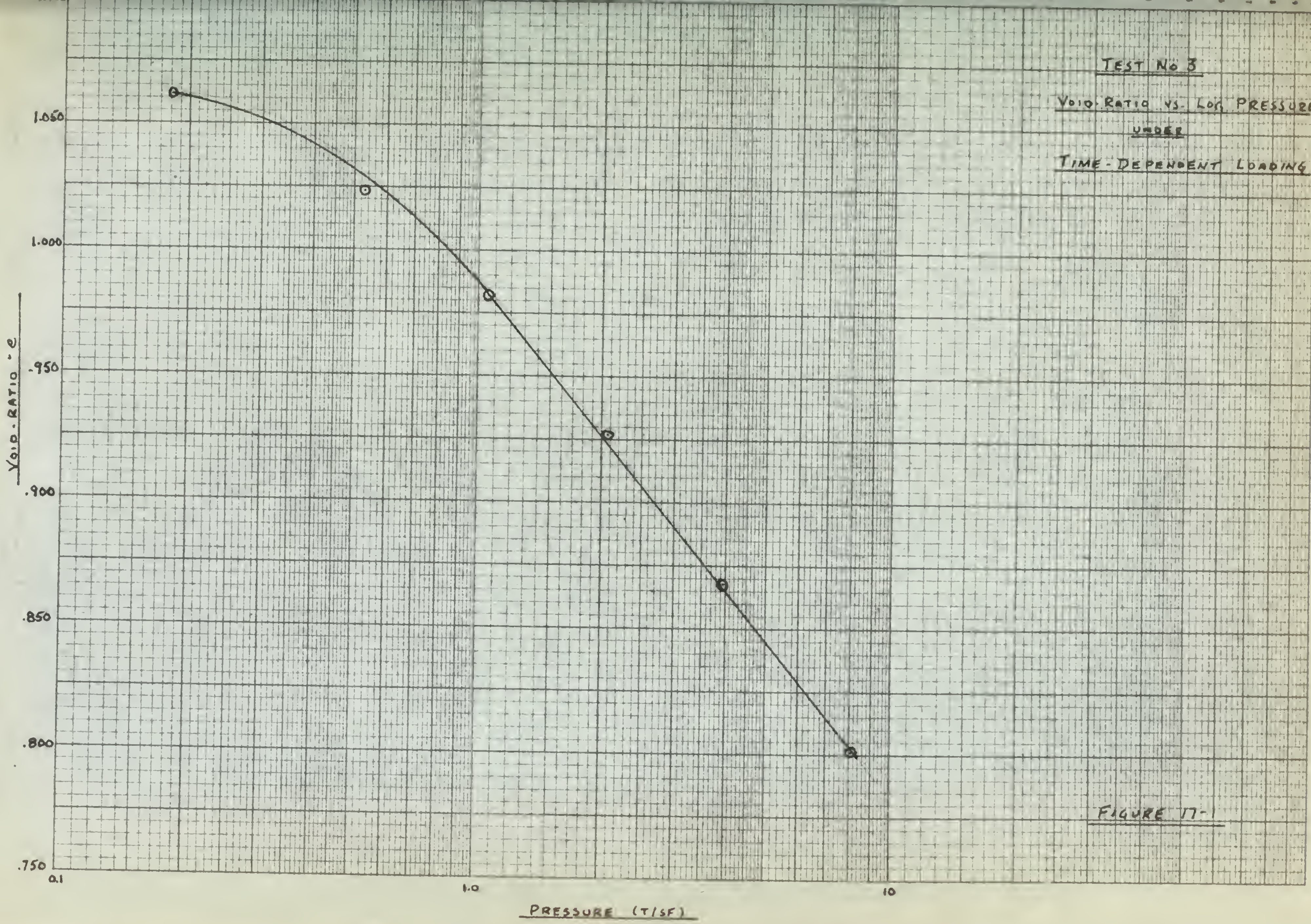
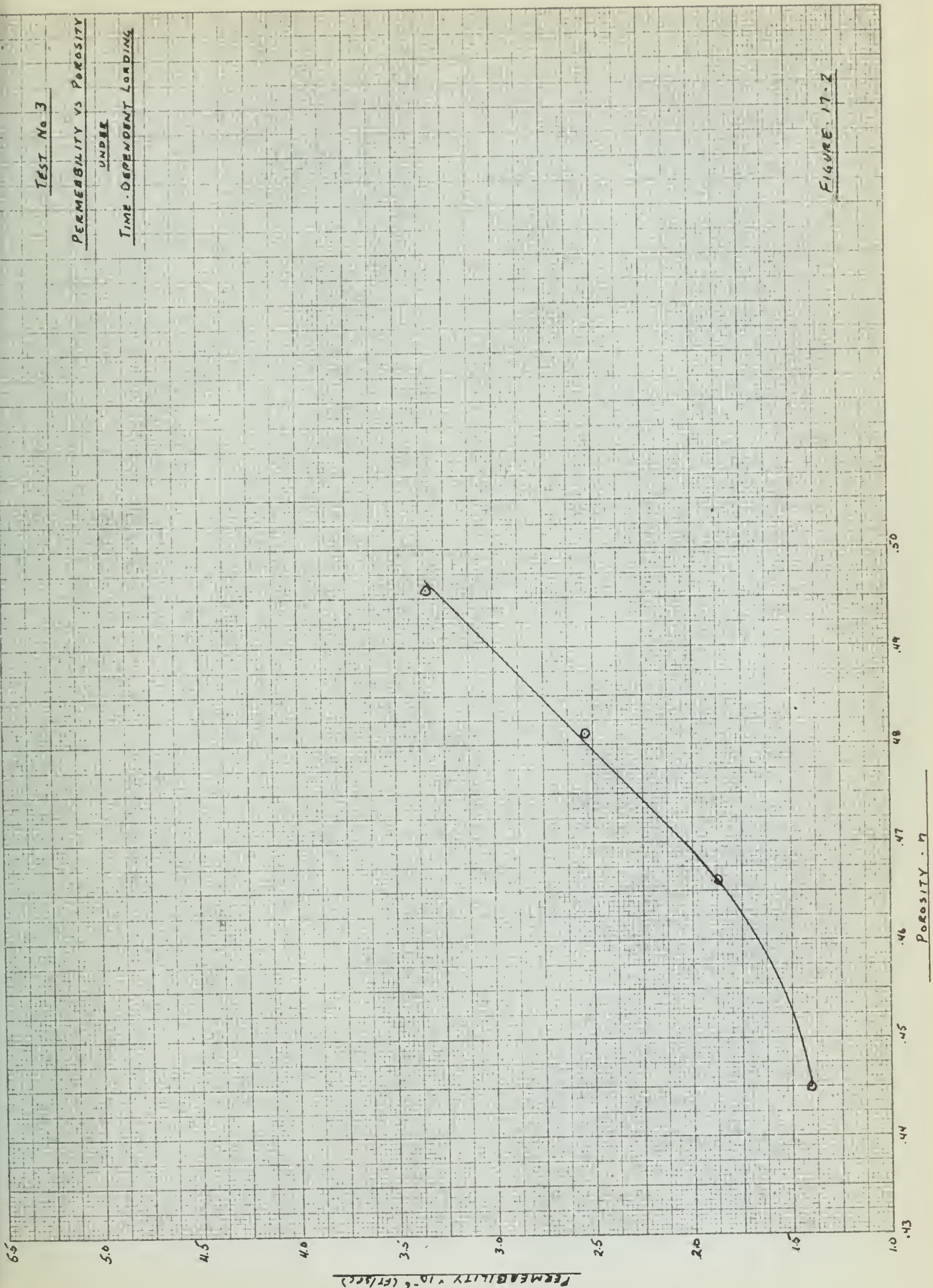

TEST No 3
VOID RATIO vs. LOG PRESSURE
UNDER
TIME-DEPENDENT LOADING
VOID-RATIO - e
1.050
1.000
.950
.900
.850
.800
.750
0.1
1.0
10
PRESSURE (T/SF)

FIGURE 17-1



Test No 3

Permeability vs Porosity under Time-Dependent Loading

Figure 17-2

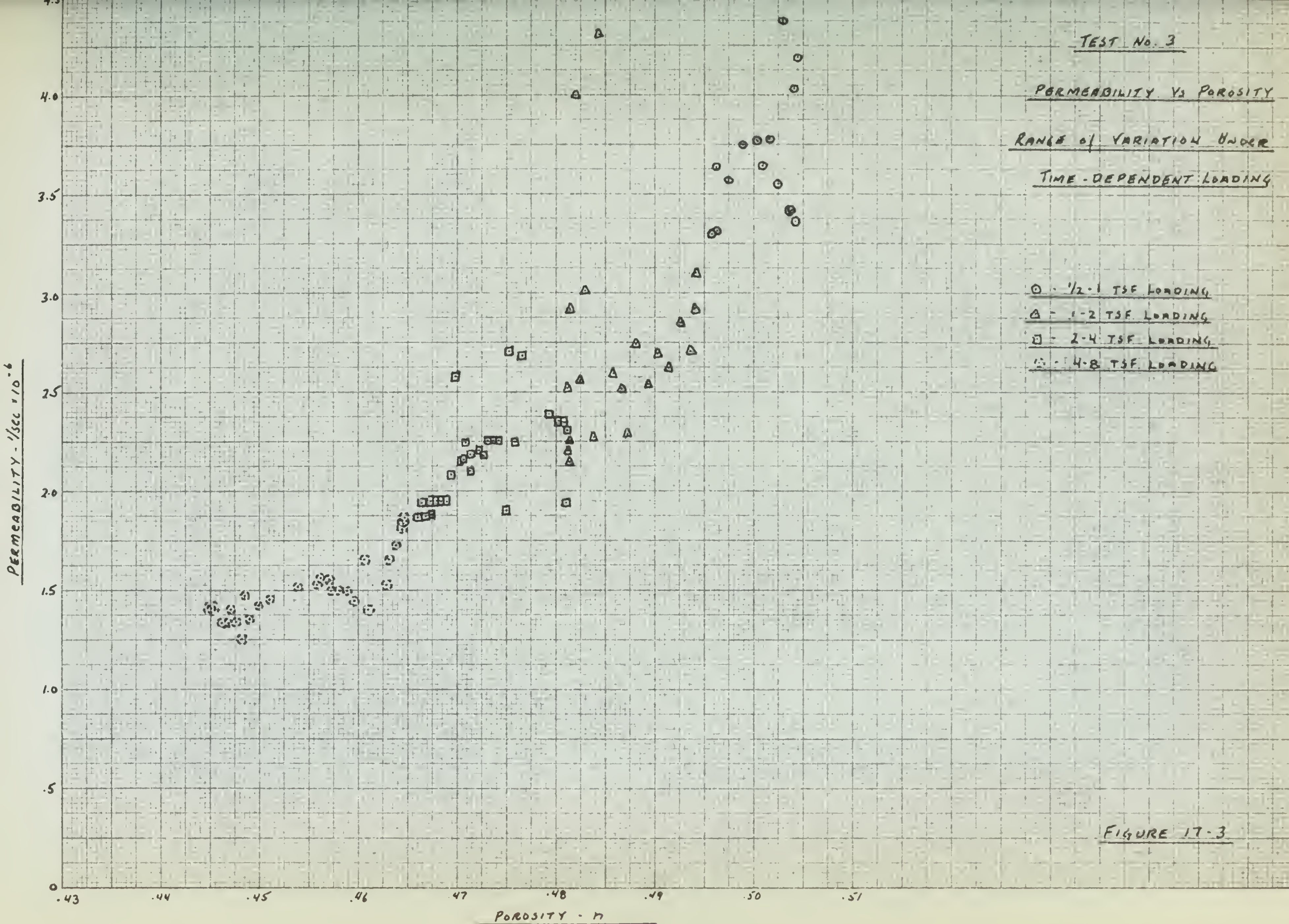

TEST No. 3
PERMEABILITY Vs POROSITY
RANGE of VARIATION UNDER
TIME - DEPENDENT LOADING
1/2 - 1 TSF LOADING
1 - 2 TSF LOADING
2 - 4 TSF LOADING
4 - 8 TSF LOADING
PERMEABILITY - 1/SEC × 10^-6
POROSITY - n
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
.43
.44
.45
.46
.47
.48
.49
.50
.51

FIGURE 17-3

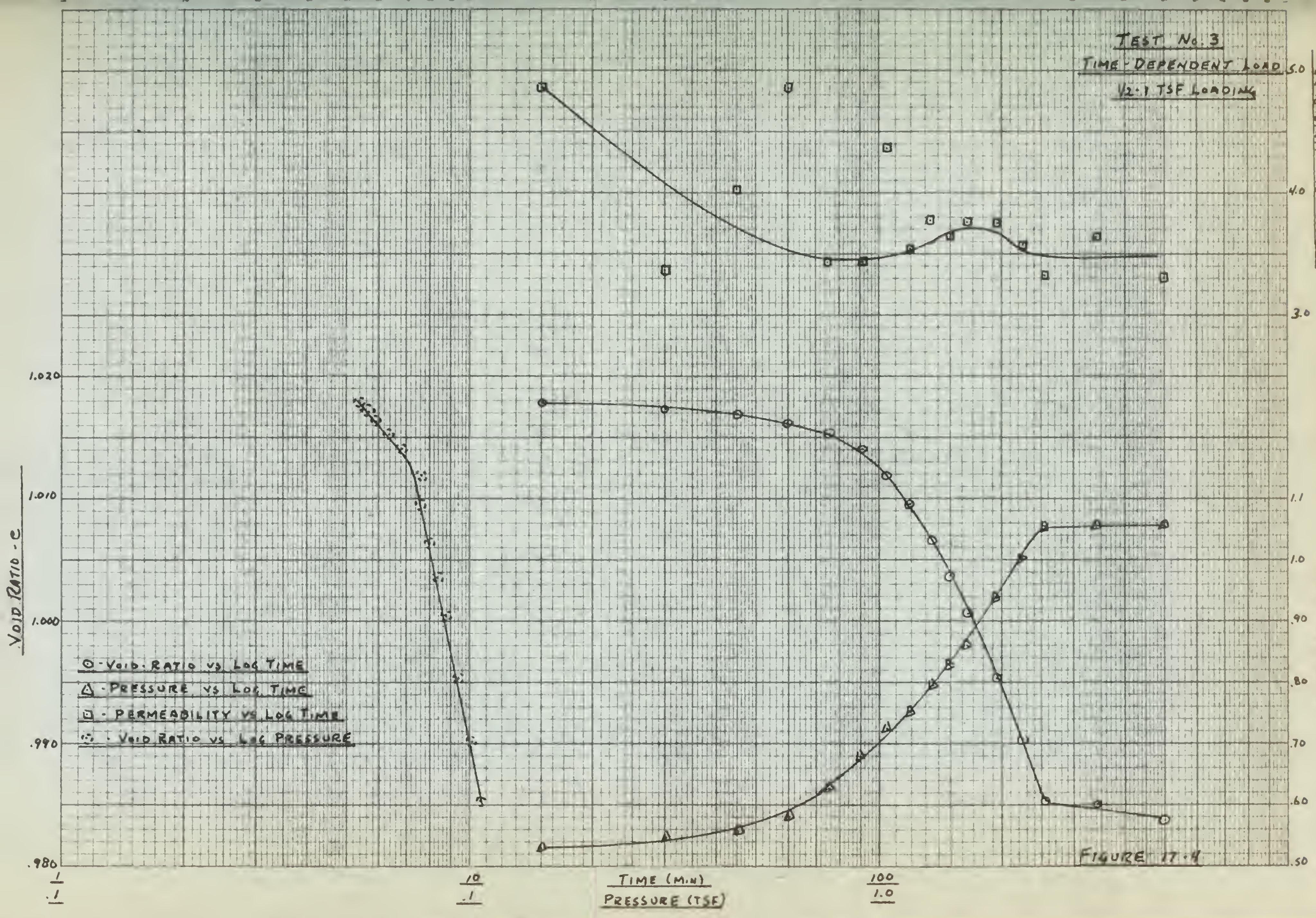
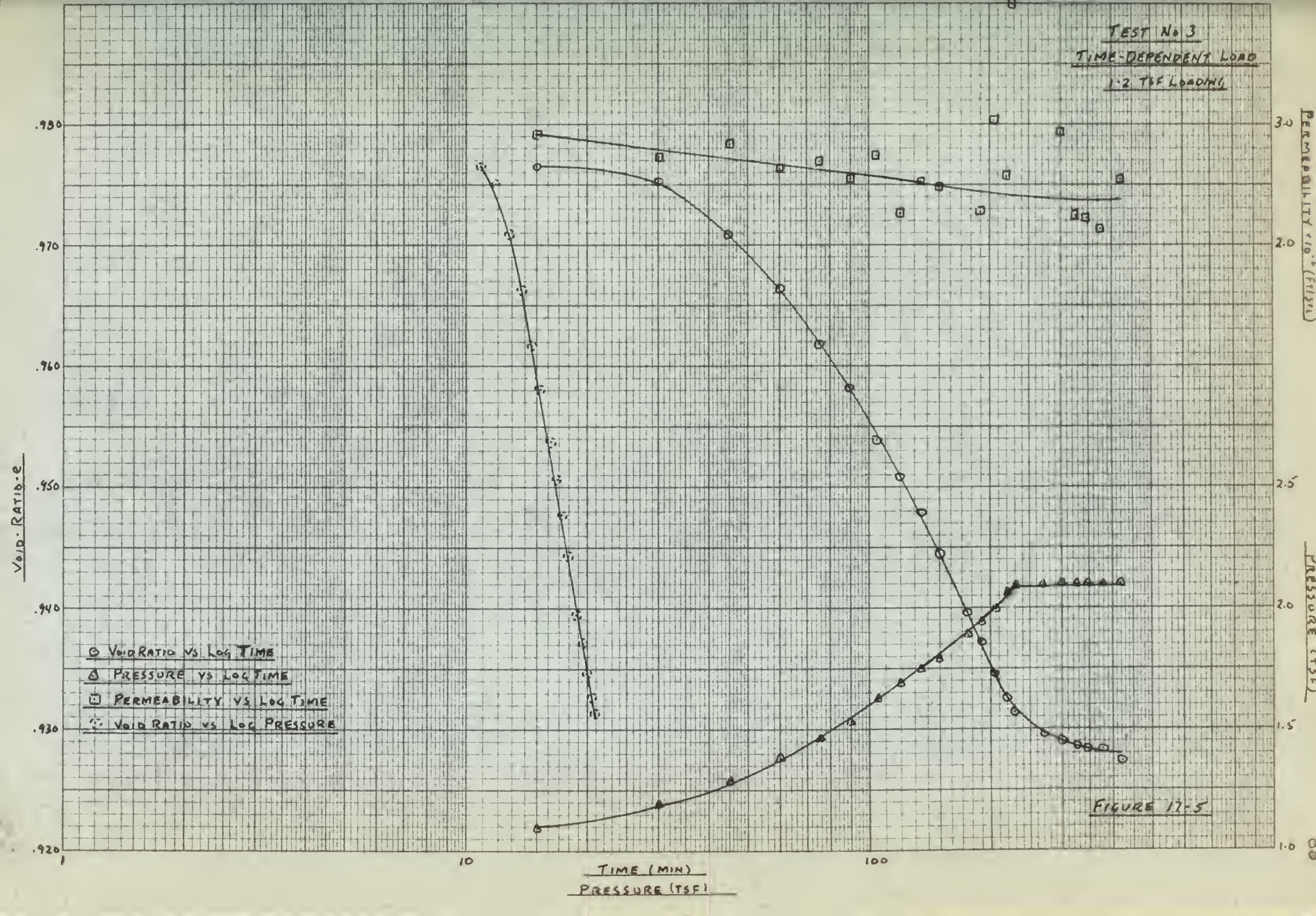

TEST No. 3
TIME - DEPENDENT LOAD
1/2 - 1 TSF LOADING
PERMEABILITY x10^-6 (Ft/Sec)
5.0
4.0
3.0
PRESSURE (TSF)
1.1
1.0
.90
.80
.70
.60
.50
VOID RATIO - e
1.020
1.010
1.000
.990
.980
⊙ - VOID RATIO VS LOG TIME
△ - PRESSURE VS LOG TIME
⊡ - PERMEABILITY VS LOG TIME
∴ - VOID RATIO VS LOG PRESSURE
1
.1
10
.1
100
1.0
TIME (MIN)
PRESSURE (TSF)

FIGURE 17.4


TEST No 3
TIME-DEPENDENT LOAD
1.2 TSF LOADING
VOID · RATIO · e
.980
.970
.960
.950
.940
.930
.920
1
10
100
TIME (MIN)
PRESSURE (TSF)
PERMEABILITY ×10⁻⁶ (FT/SEC)
3.0
2.0
2.5
2.0
1.5
1.0
PRESSURE (TSF)
VOID RATIO VS LOG TIME
PRESSURE VS LOG TIME
PERMEABILITY VS LOG TIME
VOID RATIO VS LOG PRESSURE
FIGURE 17-5

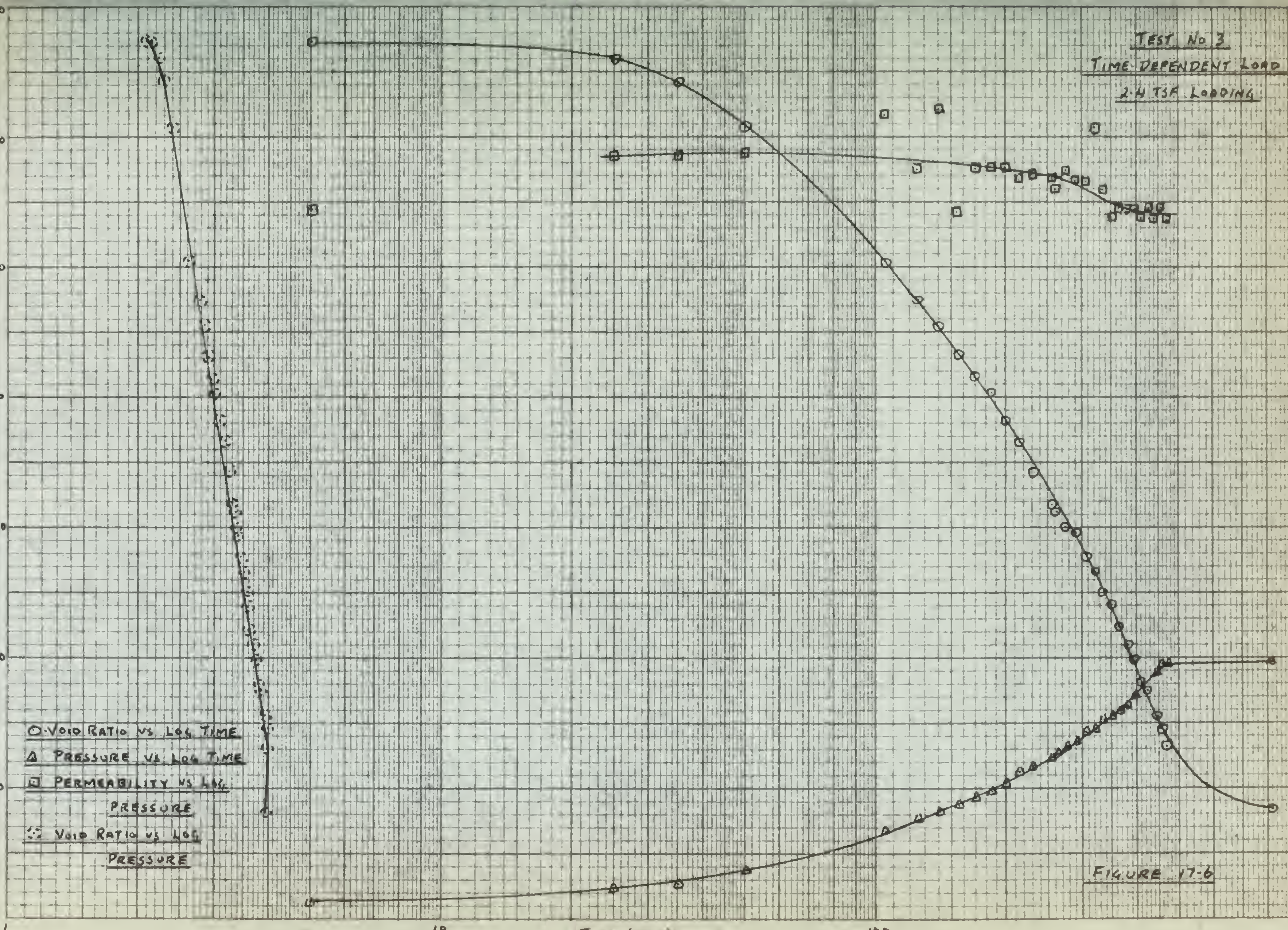
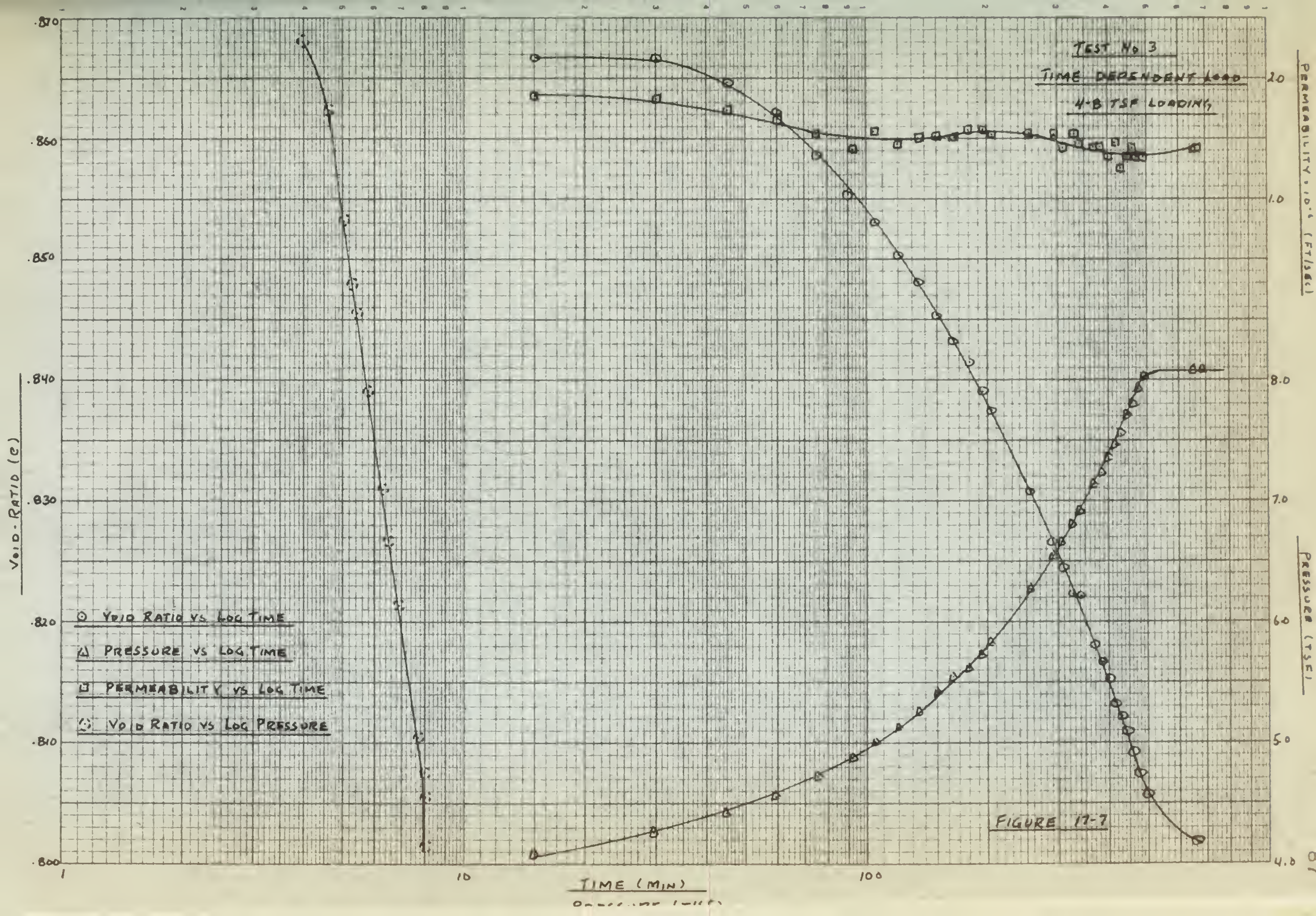


FIGURE 17-6

TIME (MIN)

PRESSURE (TSF)


TEST No 3
TIME DEPENDENT LOAD
4-8 TSF LOADING
VOID RATIO (e)
PERMEABILITY · 10⁻⁶ (FT/SEC)
PRESSURE (TSF)
TIME (MIN)
VOID RATIO VS LOG TIME
PRESSURE VS LOG TIME
PERMEABILITY VS LOG TIME
VOID RATIO VS LOG PRESSURE
.870
.860
.850
.840
.830
.820
.810
.800
2.0
1.0
8.0
7.0
6.0
5.0
4.0
1
10
100
FIGURE 17-7

D. TESTS NO. 4 - PSEUDO TIME-DEPENDENT LOADING

Test Data in graphical form is presented in Figure 18. Although it was hoped that another test of this nature could be conducted, failure of a casting in the pressure line from the bellows to the guage system precluded conducting it.

DISCUSSION:

The influence of the magnitude of the loading increment is quite apparent in data developed by this test. The deviation from standard load increments does not unduly affect the e-log P curve but it is in the k-n relationship that the effect is most apparent and requires detailed analysis. As may be seen from a study of Figure 17, the linear relationship between the permeability and the porosity is not valid in the $n \approx n_0$ region. It was therefore decided to utilize test 4, primarily to investigate the consolidation process in this area. The use of $\frac{1}{2}$ ton increments of loading, shows the permeability as a linear function of the porosity up to the 6-7 TSF range. Comparing this with Figure 17, it is noted that the straight line relationship persisted only to the 4 TSF range, in Tests No. 2 and 3. This variance can only be reasonably attributable to the influence of the loading increments. It is suggested that the instantaneous application of a major portion of the

total load in each series of tests (i.e.4TSF increments in Tests No. 2 and 3; 9 TSF in Test No. 4) causes a massive structural rearrangement which takes place in a very short time interval. The use of small increments in the early portionsof both series of tests produces a gradual structural rearrangement which takes place during a much longer time interval. A comparison of the relative curve shapes at 7 TSF in each series of tests shows the effect of this load application variance. In Tests 2 and 3 the k-n curve in this region is definitely exponential, whereas in Test 4 it approaches linearity

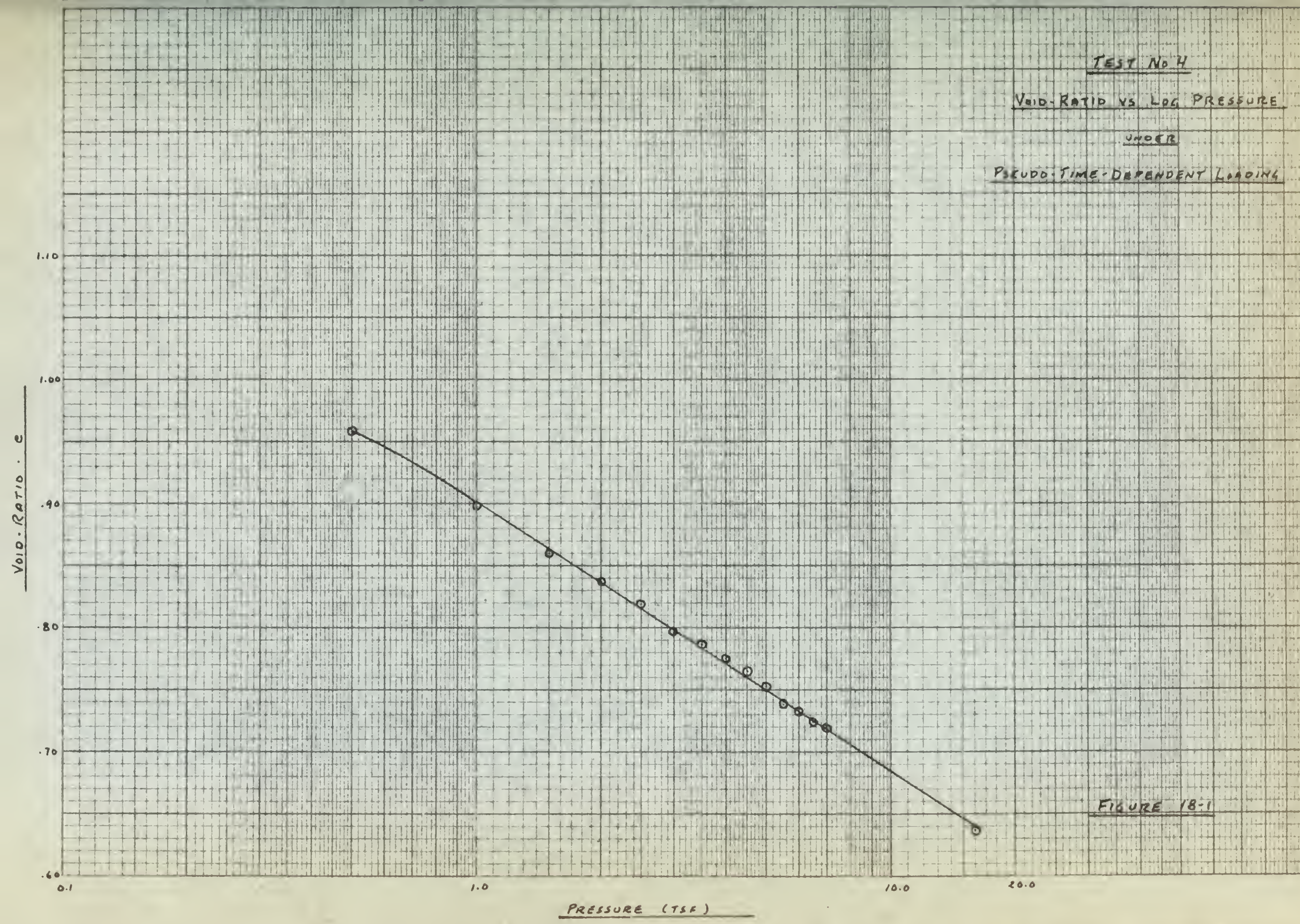
A pertinent question at this point is whether the linear relationship between k and n would continue through additional small load increment cycles until such time as a large load is applied, or whether, at some point, the permeability will asymtotically approach a condition of constancy over a large change in porosity until shear failure occurs. It is hypothesized, from the limited test data available, that the latter will occur. The physical phenomenon involved would indicate that the gradual rearrangement of structure induced by small loading increments produces a net reduction in pore-channel effective area, despite the shearing of bound water previously

discussed. In effect, the amount of shearing occuring, under small load increments, is not sufficient to retain the initial effective area and, thus, permeability decreases at a linear rate with the porosity. If however we consider the application of a large load increment, the shearing of the bound water is of such magnitude that the effective pore-channel area is reduced at a much lower rate than the sample is compressing. In effect we have retained a great portion of the effective channel area despite a reduction in porosity.

The extension of this phenomenon to include all loading, up to the point where plastic flow will occur, is of course a large jump in the process of research investigation, and is subject to justifiable criticism. However, it is proposed in the hope that future investigators in this area, may study the problem in detail and by such study arrive at a rational analysis of the cause of the phenomenon.

The importance of detailed analysis of the k-n relationship is realized when one considers that the accuracy of time-settlement predictions, by either the Terzaghi Theory or the Schiffman Extension, depend upon the porosity-permeability relationship, in that the dissipation of hydrostatic excess pressure

is governed by the availability of "effective" pore channels for flow. Since by the hypothesis proposed above, this relationship is controlled not only by the rate of loading but also by the amount of load, it is apparent that further study of this problem is essential to a clearer analysis of the constant permeability over a finite time increment approximation, of the variable permeability condition, utilized by Schiffman.



TEST No 4
VOID-RATIO VS LOG PRESSURE
UNDER
PSEUDO-TIME-DEPENDENT LOADING
1.10
1.00
.90
.80
.70
.60
0.1
1.0
10.0
20.0
VOID-RATIO · e
PRESSURE (TSF)

FIGURE 18-1

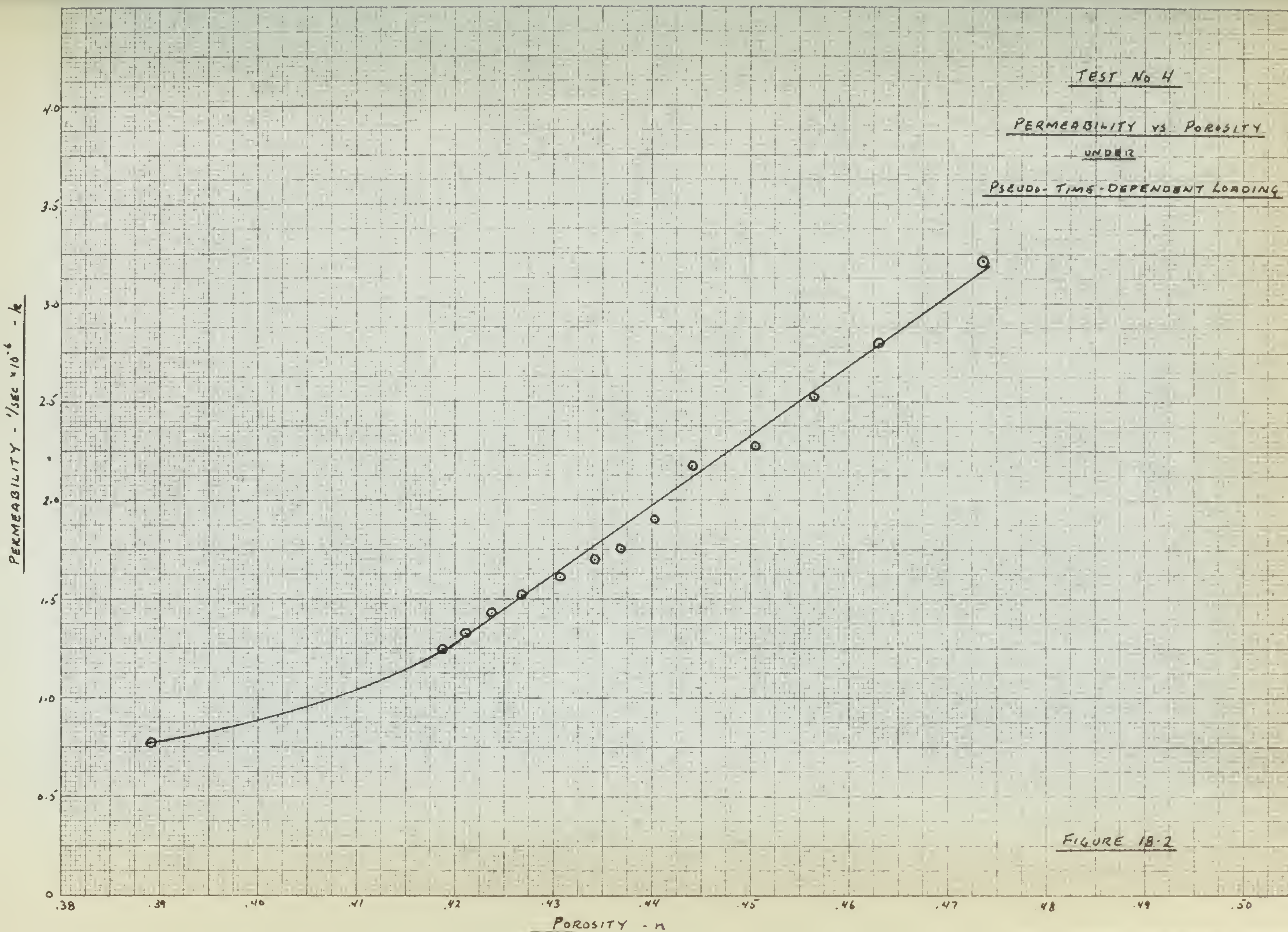

Test No 4
Permeability vs Porosity
under
Pseudo-Time-Dependent Loading
Permeability - 1/sec × 10⁻⁶ - k
Porosity - n
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
.38
.39
.40
.41
.42
.43
.44
.45
.46
.47
.48
.49
.50

FIGURE 18-2

PART VI.

CONCLUSIONS

1. The assumption of linear variation of permeability and porosity as proposed by Schmid, and utilized by Schiffman in developing his Extension to the Theory of Consolidation is valid for construction type loading (ie. small loads applied over long time periods in repetitive sequence).
2. The assumption of linear variation of permeability and porosity is not valid under conditions of large absolute load increments applied during a short time interval.
3. It is hypothesized that an exponential relationship exists between permeability and porosity for the conditions stated in 2 above. The value of the exponential relationship is a function not only of the rate of loading, but also of the magnitude of the load increment and it is suggested that such an effect is caused by the shearing of the water hull from the clay particles under intense densification of structure during a short time period. It is strongly recommended that further investigation be conducted at higher load increments to test the validity of this hypothesis.

4. It is further suggested that the permeability variance, previously referred to as the "yo-yo" effect, requires that, for the finite increment approximation in the Variable Permeability case, developed by Schiffman, the increments must be kept as small as possible. This limits the general usefullness of the approximation, since practical laboratory techniques preclude constant attendance. As noted by Schiffman (9) the degree of accuracy is a function of the time increments utilized. Since the variance of permeability is neither predictable nor always present, the use of the approximation technique for the solution of the variable permeability problem requires further investigation and analysis before a definitive conclusion can be drawn.

5. No conclusion is drawn relative to the consolidation-permeability-time relationship since fitting procedures for comparison of test curves and the theoretical curves developed by Schiffman, have not been established. It is inferred from the permeability-porosity relationships, developed during this study, that the rate of loading and amount of load will also govern the solution of this problem.

PART VII

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APPENDIX A

RAW DATA

TEST NO. 1

TEST No 1 — 1

Time	Δt	Pressure	DIAL	DIAL-IU	HT	VOL	V_s	$e = V/V_s - 1$	$n = e/1+e$	Perm. GAGE	ΔQ-cc	$K \cdot 1/sec \times 10^{-6}$	
1130	5	0 TSF	1-20	0220	1.[illegible]	4 969	2 [illegible]7	1 [illegible]111	.5171				
	10 sec		2-10	.0410	.9810	4 917		[illegible]	[illegible]				
	20		76	.0436	.9764	4 904		[illegible]	[illegible]				
	30		[illegible]	[illegible]	.9755	4 [illegible]	$\frac{1}{V_s}$ 422	[illegible]	[illegible]				
	[illegible]		70	.0470	.9750	4 78[illegible]		[illegible]	5041				
	50		83	.04[illegible]	.9727	4 7[illegible]		[illegible]	[illegible]				
1131	60		9.4	[illegible]	9726	4 77[illegible]		[illegible]	[illegible]27				
	1½		[illegible]	[illegible]	[illegible]	4 763		[illegible]	[illegible]				
	2		[illegible]	[illegible]	[illegible]	4 754		[illegible]	[illegible]				
	3		16.1	[illegible]	[illegible]	4 743		[illegible]	[illegible]				
	4		[illegible]	[illegible]	[illegible]	4 7[illegible]		[illegible]	4[illegible]				
[illegible]	5		[illegible]	[illegible]	.9625	4 726		[illegible]	4185				
	10		2-[illegible]	[illegible]	9568	[illegible]		[illegible]	[illegible]				
	20		116	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	30		146	.0746	[illegible]	[illegible]		[illegible]	[illegible]				
1230	[illegible]		17[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
1330	120		1[illegible]8	.078[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
[illegible]	240		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
1130	4[illegible]	25	[illegible]	[illegible]	[illegible]	4 [illegible]27		[illegible]	[illegible]				
[illegible]	0 SE[illegible]	2[illegible]	4 22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
	10		82	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	20		90	[illegible]	[illegible]	[illegible]	$\frac{1}{V_s}$ [illegible]	[illegible]	[illegible]				
	30		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	40		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	50		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	60		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	1½ MIN		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	2		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	3		16.3	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	4		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	5		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	10		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
	20		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	1763				
	[illegible]		5-[illegible]3	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
[illegible]	60		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
[illegible]	120		17	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
[illegible]	2[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				
[illegible]	4[illegible]	[illegible]	27	[illegible]	919[illegible]	[illegible]		[illegible]	[illegible]				
[illegible]	[illegible]	.50	5-38	1038	[illegible]	4 506		9023	[illegible]	[illegible]			
	5		64	.1064	.9156	4 496		[illegible]	.4779	[illegible]			
	10		72	1072	914[illegible]	4 497		.8956	4724	[illegible]			
	20		[illegible]	.1081	[illegible]	4 487		[illegible]	[illegible]	60			
	[illegible]		[illegible]	1087	9133	4 484		8922	[illegible]	54			
	40		[illegible]2	1092	9128	4 487		[illegible]	4712	.58			
	50		[illegible]	1096	9124	4 4[illegible]		8905	4710	.58			
[illegible]	60		[illegible]	1100	9120	4 478		[illegible]	47[illegible]	.57			
	1½		[illegible]	.1108	9112	4 474		[illegible]80	4703	57			
	2		114	1114	9106	4 471		88[illegible]7	[illegible]	56			
	3		[illegible]	1120	9100	4 466		[illegible]	[illegible]	[illegible]	.02	[illegible]	
	4		124	.1124	9096	4 466		[illegible]	4613	54	.01	[illegible]	
	5		127	.1127	[illegible]	4 464		[illegible]	[illegible]	.10	.01	10.0	
	10		[illegible]	.1134	9086	4 461		[illegible]	[illegible]	75	15	3[illegible]0	
	20		[illegible]	.1137	9081	[illegible]		[illegible]	[illegible]	1.07	.22	3[illegible]6	
	30		[illegible]	.1143	9077	4 4[illegible]7		[illegible]	[illegible]	1.36	.24	30.6	
[illegible]	60		[illegible]	1148	[illegible]	4 454		[illegible]	[illegible]	2.32	[illegible]	33[illegible]	
[illegible]	1.0		[illegible]	1153	9067	4 4[illegible]2		[illegible]	[illegible]	4.27	[illegible]	21.1	
[illegible]	[illegible]		[illegible]	1159	9062	4 441		8174	[illegible]	[illegible]	[illegible]	24.4	
[illegible]	[illegible]	.75	[illegible]	1162	905[illegible]	4 441		8762	[illegible]	16.[illegible]4	[illegible]12	[illegible]	

TEST No. 1

TIME	Δt	Pressure	DIAL	DIAL-IN	HT	VOL	Vs	e = V/Vs - 1	n = e/1+e	PERM. GAGE	ΔQ-cc	K - 1/sec × 10⁻⁶
1415	0 sec	.75	5 - 19.6	.1198	.9022	4.425	2.37	[illegible]	.46[illegible]	.62		
	10		6 - 1.4	.1214	.9006	4.422		[illegible]	.4[illegible]	.67		
	20		2.1	.1221	.8999	4.419		.8648	.4637	.61		
	30		[illegible]	.1225	.8995	4.417	.422	.8639	.4634	.61		
	40		2.9	.1229	.8991	4.415		[illegible]	.4632	.61		
	50		3.1	.1231	.8989	4.414		.8[illegible]27	.4631	.61		
	60		3.4	.1234	.89[illegible]	4.412		[illegible]	.4628	.61		
	1½ min		3.9	.1239	.8981	4.410		.8610	.4626	.61		
	2		4.3	.1243	.8977	4.408		.8601	.4623	.62	.01	1.06
	3		4.8	.1248	.8972	4.405		[illegible]	.4620	.64	.02	2.06
	4		5.2	.1252	.8968	4.403		.85[illegible]	.4617	.67	.07	3.14
	5		5.4	.1254	.8966	4.402		.8576	.4616	[illegible]	.12	2.06
	10		6.1	.1261	.8959	4.399		.8563	.4612	[illegible]	.14	2.77
	20		6.7	.1267	.8953	4.396		.8551	.4609	1.12	.29	3.04
	30		7.0	.1270	.8950	4.394		.8542	.4607	1.47	.30	3.13
1515	60		7.8	.1278	.8942	4.391		.8530	.4603	[illegible]	.81	3.13
1615	120		8.4	.1284	.8936	4.388		.8517	.4599	4.18	1.87	3.21
1815	240		9.0	.1290	.8930	4.385		.8504	.4595	[illegible]	4.15	3.51
2215	480	1.00	9.4	.1294	.8926	4.383		.8496	.4592	1.26	7.05	3.03
0900	0 sec	1.00	6 - 11.4	.1314	.8906	4.378		.847[illegible]	.45[illegible]	1.87		
	10		7 - 6.0	.1460	.8760	4.3[illegible]		.81[illegible]	.44[illegible]			
	20		9.3	.1493	.8727	4.285		.8082	.44[illegible]	1.[illegible]		
	30		11.6	.1516	.8704	4.274		.8036	.4453	1.[illegible]		
	40		13.1	.1531	.8[illegible]	4.266		.8001	.4444	1.10		
	50		14.2	.1542	.8678	4.261		.7981	.4438	1.3[illegible]		
	60		15.0	.15[illegible]	.8670	4.257		.7964	.4433	1.2[illegible]		
	1½ min		16.6	.1566	.8654	4.248		.7930	.4422	1.22		
	2		17.4	.1574	.8646	4.245		.7913	.4417	1.2[illegible]		
	3		[illegible]	.1581	.8639	4.242		.7901	.4413	1.2[illegible]		
	4		18.5	.1585	.8635	4.240		.7892	.4411	1.23	.03	3.02
	5		18.8	.1588	.8632	4.238		.7884	.44[illegible]	1.2[illegible]	.07	1.98
	10		19.4	.1594	.8626	4.235		.7871	.4404	1.36	.11	2.24
	20		19.9	.1599	.8621	4.233		.7863	.440[illegible]	1.60	.24	2.32
	30		8 - 0.2	.1602	.8618	4.231		.7854	.4399	1.87	[illegible]	2.32
1000	60		0.7	.1607	.8613	4.229		.7846	.4396	2.56	.73	2.41
1100	120		1.4	.1614	.8606	4.226		.7833	.4392	4.[illegible]	1.41	2.49
1300	240		2.0	.1620	.8600	4.223		.7821	.4388	7.28	3.23	2.66
1650	470	2.00	2.5	.1625	.8595	4.220		.7806	.4384	[illegible]	5.80	2.47
1230	0 sec	2.00	8 - 4.5	.1645	.8575	4.210		.776[illegible]	.4371	1.9[illegible]		
	10		19.6	.1796	.8424	4.136		.74[illegible]3	.4270	1.6[illegible]		
	20		9 - 2.9	.1829	.8391	4.120		.7386	.4248	1.[illegible]		
	30		5.4	.1854	.8[illegible]	4.109		.73[illegible]	.4227	1.44		
	40		6.3	.1863	.8357	4.103		.7314	.4224	1.[illegible]		
	50		7.7	.1877	.8343	4.096		.7285	.4214	1.36		
	60		8.3	.1883	.8337	4.093		.7272	.4210	1.35		
	1½ min		9.3	.1893	.8327	4.0[illegible]4		.7255	.4204	1.[illegible]		
	2		9.8	.1898	.8322	4.0[illegible]		.7247	.4200	1.31		
	3		10.3	.1903	.8317	4.084		.7234	.4197	1.[illegible]		
	4		10.6	.1906	.8314	4.082		.7226	.4191	1.32	[illegible]	.914
	5		10.8	.1908	.8312	4.081		.7221	.4193	1.35	.3	2.11
	10		11.4	.1914	.8306	4.078		.72[illegible]	.418[illegible]	1.42	.07	1.76
	20		11.9	.1919	.8301	4.076		.7201	.4156	1.60	.15	1.74
	30		12.1	.1921	.8299	4.075		.7196	.4154	1.79	[illegible]	1.82
1330	60		12.6	.1926	.8294	4.072		.7183	.41[illegible]	2.38	[illegible]	1.91
1430	120		13.1	.1931	.8289	4.0[illegible]		.717[illegible]	.4177	3.42	1.44	2.23
1630	210		13.6	.1936	.8282	4.066		.71[illegible]	.4172	[illegible]	[illegible]	2.22
2030	4[illegible]	4.00	14.4	.1944	.8276	4.064		.71[illegible]	.41[illegible]	11.63	4.13	2.13

TEST No 1

TIME	Δt	PRESSURE	DIAL	DIAL · IN	HT	VOL	Vs	e = V/Vs − 1	n = e/1+e	PERM GAGE	ΔQ · cc	K · 1/sec ×10⁴
1415	0 SEC	4.00	9-16.1	.1961	.8251	4.155	2.37	.7112	.415	1.20		
	10		10-13.3	.2122	.8187	3.971		.6756	.4032	.50		
	20		16.8	.2168	.8052	3.954	⊥ .422	[illegible]	.4006	.7[illegible]		
	30		11.1	.2191	.8024	3.942	Vs	.6635	[illegible]	.6[illegible]		
	40		11-0.4	.2204	.8016	3.936		.6610	3479	[illegible]		
	50		1.1	.2211	.8009	3.932		.6593	3473	[illegible]		
	60		1.6	.2216	.8004	3.930		.6585	.3470	.58		
	1½ MIN		2.4	2224	7996	3.926		.6571	3463	.57		
	2		2.7	.2227	7993	3.925		6563	3462	.56		
	3		3.2	.2232	7988	3.922		.6550	3457	.57	.01	.57
	4		3.5	2235	7985	3.921		.6546	3456	.58	[illegible]	.81
	5		3.7	2237	7983	3.920		.6542	.3454	.59	.01	.61
	10		4.3	2243	.7977	3.917		.6529	.3450	.65	.07	1.11
	20		4.9	2249	7971	3.914		.6517	.3445	.72	.14	1.27
	30		5.2	2252	7968	3.912		.6507	3442	.73	.14	1.27
1515	60		5.7	2257	7963	3.910		.6501	3421	1.41	.56	1.75
1615	120		6.4	2264	7956	3.906		.6483	3433	2.32	.83	1.27
1815	240		7.1	2271	7949	3.903		6.470	.3424	4.7	1.73	1.51
2215	480	8.00	7.7	2277	7943	3.900		.6458	3423	8.16	3.11	1.51

SAMPLE DATA

SPECIFIC GRAVITY	2.59
INITIAL HT of SAMPLE	1.0000 IN.
FINAL HT of SAMPLE	.7943 IN
CROSS SECTIONAL AREA	4.9087 IN²
INITIAL MOISTURE CONTENT	42 %
FINAL MOISTURE CONTENT	31.7 %
WT of SOLIDS	102.5 grams
VOL of SOLIDS	2.365 IN³

APPENDIX B

RAW DATA

TEST NO. 2

TEST No 2

1

TIME	Δt · MIN	LOAD · PSI	LOAD · TSF	DIAL	DIAL · IN	HT.	VOL. = V	V_s	$e = V/V_s - 1$	$n = e/1+e$	PERM. GAGE	ΔQ · cc	K · ft/sec
1015	0	0		0 - 0.0	0.0000	1.0000	4.9087	2.29	2.1431 - 1	.5333			
1024	9	.050	.0166	0.1	.0001	.9999	4.9082		2.1429	.5333			
1033	9	.070	.0233	0.2	.0002	.9998	4.9077		2.1427	.5332			
1100	45	.09	.0299	0.3	.0003	.9997	4.9072	$\frac{1}{V_s}$ = .4366	2.1424	.5332			
1130	75	.12	.0399	1.0	.0010	.9990	4.9037		2.1409	.5329			
1200	105	.22 + .05	.0899	6.3	.0063	.9937	4.8777		2.1296	.5304			
1230	135	.25	.0899	12.8	.0128	.9872	4.8458		2.1156	.5273			
1300	165	.38	.1431	16.0	.0160	.9840	4.8301		2.1088	.5257			
1330	186	.51 + .08	.1964	1 - 3.5	.0235	.9765	4.7933		2.0927	.5221			
1400	225	.63	.2364	4.7	.0247	.9753	4.7874		2.0901	.5215			
1430	255	.85	.3096	8.2	.0282	.9718	4.7702		2.0826	.5198			
1500	285												
1530	315												
1000	0	.85 + .08	.3096	1 - 5.4	.0254	.9756	4.7889		2.0908 - 1	.5217			
	10 SEC			6.9	.0269	.9731	4.7766	2.29	2.0854	.5204			
	20			7.4	.0274	.9726	4.7742		2.0844	.5202			
	30			7.5	.0275	.9725	4.7737		2.0841	.5202			
	40			7.6	.0276	.9724	4.7732	$\frac{1}{V_s}$ = .4366	2.0839	.5201			
	50			7.7	.0276	.9723	4.7730		2.0838	.5201			
	60			7.7	.0277	.9723	4.7727		2.0837	.5201			
	1.5 MIN			7.7	.0277	.9723	4.7727		2.0837	.5201			
	2			7.8	.0278	.9722	4.7722		2.0835	.5200			
	3			7.8	.0278	.9722	4.7722		2.0835	.5200			
	4			7.8	.0278	.9722	4.7719		2.0834	.5200			
1005	5			7.9	.0279	.9721	4.7717		2.0834	.5199			
1010	10			8.0	.0280	.9720	4.7712		2.0831	.5199			
1020	20			8.2	.0282	.9718	4.7702		2.0826	.5198			
1035	35	.86	.3130	8.6	.0286	.9714	4.7683		2.0818	.5196			
1045	45	.87	.3163	9.0	.0290	.9710	4.7663		2.0809	.5194			
1145	105	.93 + .12	.3496	13.5	.0335	.9665	4.7442		2.0713	.5172			
1215	135	1.02	.3796	16.7	.0367	.9663	4.7285		2.0644	.5155			
1230	150	1.05	.3896	18.1	.0381	.9619	4.7216		2.0614	.5148			
1245	165	1.07	.3962	19.2	.0392	.9608	4.7162		2.0590	.5143			
1400	180	1.20 + .16	.4528	2 - 2.2	.0422	.9578	4.7015		2.0536	.5128			
1415	195	1.23	.4628	3.2	.0432	.9568	4.6966		2.0505	.5123			
1500	240	1.30	.4995	5.2	.0452	.9548	4.6868		2.0462	.5112			
1530	270	1.32	.4928	6.1	.0461	.9539	4.6824		2.0443	.5108			
1600	300	1.35	.4995	7.0	.0470	.9530	4.6779		2.0423	.5103			
1630	330	1.38	.5094	7.7	.0477	.9523	4.6745		2.0408	.5099			
1700	360	1.42	.5228	8.5	.0485	.9515	4.6706		2.0391	.5095			
1730	390	1.45 + .20	.5494	9.1	.0491	.9509	4.6676		2.0378	.5092			
1800	420	1.50	.5661	10.0	.0500	.9490	4.6583		2.0365	.5084			
0910	0	1.50 + .20	.5661	2 - 10.1	.0561	.9498	4.6632	2.29	2.0360 - 1	.5088	1.90	0	
	15 SEC										1.91	.01	4.43×10^{-6}
	30										1.92	.01	4.43×10^{-6}
	45							$\frac{1}{V_s}$ = .4366			1.93	.01	4.43×10^{-6}
	60										1.94	.01	4.43×10^{-6}
	1½ MIN										1.96	.02	4.43×10^{-6}
	2										1.99	.03	6.74×10^{-6}
	3										2.01	.02	2.21×10^{-6}
	4										2.03	.02	2.21×10^{-6}
0915	5										2.07	.04	4.43×10^{-6}
0920	10										2.32	.25	5.54×10^{-6}

TEST No 2 -(CONT) 2

TIME	Δt	LOAD-PSI	LOAD-TSF	DIAL	DIAL-IN.	HT	VOL. = V	V_s	$e = V/V_s - 1$	$n = e/1+e$	PERM. GAGE	ΔQ-cc	$K \cdot 1/sec \times 10^{-6}$
0930	20 MIN	1.50 + .20	.5661	2-10.2	.0502	.9498	4.6627	2.29	2.0357 - 1	.5087	2.73	.61	6.76
0940	30	1.50	.5661	-10.2	.0502	.9498	4.6627		2.0357	.5087	3.17	.44	3.66
1010	60	1.55	.5827	-10.3	.0503	.9497	4.6617		2.0352	.5086	4.44	1.27	4.69
1040	90	1.57	.5894	10.5	.0505	.9495	4.6608		2.0349	.5086	5.72	1.28	4.73
1110	120	1.62	.6060	11.0	.0510	.9490	4.6583	$\frac{1}{V_s} = .4366$	2.0338	.5083	7.03	1.31	4.83
1140	150	1.66	.6193	11.7	.0517	.9483	4.6549		2.0323	.5079	8.23	1.20	4.43
1210	180	1.72	.6393	12.9	.0529	.9471	4.6490		2.0297	.5073	9.45	1.22	4.49
1240	210	1.79	.6626	14.2	.0542	.9458	4.6426		2.0269	.5066	10.67	1.22	4.48
1310	240	1.87	.6893	15.5	.0555	.9445	4.6362		2.0241	.5059	11.90	1.23	4.52
1340	270	1.90	.6993	16.8	.0568	.9432	4.6298		2.0213	.5052	13.14	1.24	4.54
1410	300	1.95	.7159	17.9	.0579	.9421	4.6244		2.0189	.5046	14.24	1.10	4.04
1440	330	1.99	.7292	18.8	.0588	.9413	4.6227		2.0173	.5044	15.26	1.02	3.74
1510	360	2.04	.7459	19.7	.0597	.9403	4.6205		2.0166	.5042	16.43	1.07	3.90
1540	390	2.10 + .25	.7825	3-0.3	.0603	.9397	4.6127		2.0139	.5034	17.66	1.23	4.47
1610	420	2.18	.8091	2.1	.0621	.9379	4.6038		2.0100	.5024	18.72	1.06	3.92
1640	450	2.30	.8491	4.2	.0642	.9358	4.5935		2.0055	.5013	19.86	1.14	4.15
1710	480	2.40 + .28	.8824	6.2	.0662	.9338	4.5837		2.0012	.5002	20.98	1.12	4.06
2215	785	2.40	.8924	10.0	.0700	.9300	4.5660		1.9930	.4982			
0830	0 MIN	2.40 + .28	.8924	3-11.7	.0717	.9283	4.5567		1.9894 - 1	.4473	0.40	0	3.76
0835	5	2.55	.9423	11.9	.0719	.9281	4.5557	2.29	1.9890	.4472	.60	.20	4.22
0840	10	2.70	.9923	12.9	.0729	.9271	4.5508		1.9868	.4966	.76	.16	3.46
0845	15	2.80	1.0256	13.8	.0738	.9262	4.5464		1.9849	.4961	.90	.14	3.03
0850	20	2.90	1.0589	15.7	.0757	.9243	4.5371	$\frac{1}{V_s} = .4366$	1.9808	.4951	1.20	.30	6.52
0930	60	4.00 + .32	1.4385	4-10.0	.0900	.9100	4.4664		1.9562	.4872	1.91	.71	2.61
1000	90	4.50	1.6050	15.2	.0952	.9048	4.4413		1.9346	.4842	2.66	.75	2.64
1116	166	5.00 + .40	1.7980	4.1	.1041	.8959	4.3977		1.9200	.4791	4.60	1.94	2.64
1131	181	5.65	2.0146	5.5	.1055	.8945	4.3908		1.9170	.4783	5.09	.49	3.40
1200	216	6.0	2.1312	8.0	.1080	.8920	4.3785		1.4116	.4768	5.87	.78	2.80
1240	0	6.0 + .40	2.1312	5-9.3	.1093	.8907	4.3721		1.9088 - 1	.4761	7.03	0	2.80
1250	10	6.1	2.1645	9.5	.1095	.8905	4.3711	2.29	1.9084	.4760	7.30	.27	2.69
1300	20	6.1 + .45	2.2810	10.5	.1105	.8895	4.3662		1.9062	.4753	7.56	.26	2.69
1330	50	7.25	2.5641	15.7	.1157	.8843	4.3407		1.8951	.4723	8.28	.72	2.48
1400	80	7.9 + .48	2.7900	6-0.1	.1201	.8791	4.3152	$\frac{1}{V_s} = .4366$	1.8840	.4692	8.93	.65	2.23
1435	115	8.4	2.9570	4.4	.1244	.8756	4.2980		1.8765	.4670	9.68 1.08	.75	2.20
1500	140	9.2	3.2234	7.1	.1271	.8729	4.2848		1.8707	.4654	1.62	.54	2.17
1530	170	9.8	3.4232	9.9	.1299	.8701	4.2710		1.8.647	.4637	2.26	.54	1.83
1600	200								1.				
1630	230	10.8 + .52	3.7695	14.6	.1346	.8654	4.2479		1.8546	.4608	3.56	1.30	2.19
1700	260	11.2	3.9027	16.4	.1364	.8635	4.2386		1.8505	.4596	4.21	.65	2.18
1730	290	11.6	4.0359	18.1	.1381	.8619	4.2308		1.8471	.4586	4.86	.45	1.51
1800	340	12.0	4.1691	19.8	.1398	.8602	4.2224		1.8359	.4575	5.50	.54	1.81

3

TEST No. 2 - (CONT.)

TIME	Δt - MIN	LOAD - PSI	LOAD - TSF	DIAL	DIAL - IN	HT.	VOL. = V	V	$V/V_s - 1 = e$	$n = e/_{1+e}$	PERM. GAGE	ΔQ = CC	K · ft/sec·10
0900	0	12.0 = .57	4.1858	7-3.3	.1433	.8567	4.2052		1.8359-1	.4553	0.55	0	1.80
0910	10	12.4	4.3190	3.4	.1434	.8566	4.2047	2.29	1.8357	.4552	.63	.08	0.80
0920	20	12.9	4.4855	3.7	.1437	.8563	4.2033		1.8351	.4550	.91	.28	2.80
0930	30	13.4	4.6520	4.7	.1447	.8553	4.1984		1.8330	.4544	1.07	.16	1.60
0945	45	14.2	4.9184	7.0	.1470	.8530	4.1871	$\frac{1}{V_s}$ = .4366	1.8280	.4529	1.27	.20	1.33
1000	60	14.9	5.1515	9.3	.1493	.8507	4.1758		1.8231	.4514	1.48	.19	1.21
1030	90	16.3 = .60	5.6277	14.2	.1542	.8458	4.1517		1.8126	.4483	1.89	.41	1.34
1100	120	17.4	5.9940	17.2	.1572	.8428	4.1370		1.8062	.4463	2.30	.41	1.34
1130	150	18.5 = .65	6.3769	8-0.2	.1602	.8398	4.1223		1.7996	.4443	2.73	.43	1.40
1200	180	19.4	6.6766	2.7	.1627	.8373	4.1100		1.7944	.4427	3.16	.43	1.40
1230	210	19.8	6.7932	4.0	.1640	.8360	4.1036		1.7916	.4418	3.62	.46	1.50
1255	235	20.0	6.8764	4.8	.1648	.8352	4.0997		1.7899	.4413	4.02	.40	1.51
1330	270	20.6	7.0762	5.5	.1655	.8345	4.0963		1.7884	.4408	4.58	.56	1.55
1400	300	20.8	7.1428	6.8	.1668	.8332	4.0899		1.7856	.4399	5.20	.62	
1430	330	21.0	7.2094	7.1	.1671	.8329	4.0884		1.7849	.4397	5.56	.36	1.60
1500	360	21.5	7.3759	8.0	.1680	.8320	4.0840		1.7830	.4391	6.03	.47	1.52
1530	390	21.8	7.4758	8.8	.1688	.8312	4.0801		1.7813	.4386	6.51	.48	1.54
1600	420	22.3	7.6423	9.7	.1697	.8303	4.0756		1.7794	.4380	7.00	.49	1.58
1700	450	22.8 = .68	7.8188	10.8	.1708	.8292	4.0702		1.7770	.4372	7.43	.43	1.38

SAMPLE DATA

SPECIFIC GRAVITY	2.59
INITIAL HEIGHT of SAMPLE	1.0000 IN.
FINAL HEIGHT of SAMPLE	.8292 IN.
CROSS-SECTIONAL AREA	4.9087 IN^2
INITIAL MOISTURE CONTENT	42%
FINAL MOISTURE CONTENT	32.15%
WT. of SOLIDS	97.003 Gr.
VOL. of SOLIDS	2.29 IN^3

COMPUTATIONS

$$K = \frac{QL}{AtH}$$

$$K = \frac{L(2.54)}{45(2.54)(A)(2.54)^2} \cdot \frac{Q}{t} = \frac{.007\ QL}{t}$$

H = 45"

L = HT of SAMPLE

APPENDIX C

RAW DATA

TEST NO. 3

TEST No 3

1

TIME	Δt (MIN)	LOAD PSI	LOAD TSF	DIAL	DIAL . . IN	HT.	VOL. : V	V_s	$e \cdot V/V_s - 1$	$n = e/1+e$	PERM. GAGE	ΔQ · cc	K · 1/sec 10^{-6}
1000	0	0 →	0 →	0 - 0.0	0.00	1.0000	4.909		2.1010 - 1	.5240			
1010	10			1.1	.0011	.9989	4.904	2.336	2.0989	.5236			
1020	20			2.2	.0022	.9978	4.898		2.0963	.5229			
1030	30			3.1	.0031	.9969	4.894		2.0946	.5225			
1045	45			4.2	.0042	.9958	4.888	$\frac{1}{V_s}$: .4280	2.0920	.5219			
1100	60			4.6	.0046	.9954	4.886		2.0912	.5218			
1130	90			5.1	.0051	.9949	4.884		2.0903	.5215			
1200	120	.05	.0165	6.6	.0066	.9934	4.877		2.0873	.5209			
1230	150	.15	.0495	8.2	.0082	.9918	4.869		2.0839	.5201			
1300	180	.20	.0660	8.7	.0087	.9913	4.866		2.0826	.5198			
1345	225	.35	.1155	9.1	.0091	.9909	4.864		2.0817	.5196			
1400	240	.38	.1255	9.2	.0092	.9908	4.864		2.0817	.5196			
1430	270	.45	.1485	9.3	.0093	.9907	4.863		2.0813	.5195			
1500	300	.50	.1650	9.4	.0094	.9906	4.863		2.0813	.5195			
1330		.50 + .05	.1815	18.6	.0186	.9814	4.818		2.0621	.5150			
1330	0	.75 + .05	.2540	0 - 18.6	.0186	.9814	4.818	2.336	2.0621 - 1	.5150			
1345	15	.80 + .08	.2905	1 - 0.8	.0208	.9792	4.807		2.0573	.5139			
1400	30	.85	.3067	3.0	.0230	.9770	4.796		2.0526	.5128			
1415	45	.90	.3230	4.6	.0246	.9754	4.788	$\frac{1}{V_s}$: .4280	2.0492	.5120			
1430	60	.97	.3465	5.9	.0259	.9741	4.782		2.0466	.5113			
1505	95	1.05	.3768	8.2	.0282	.9718	4.771		2.0422	.5103			
1530	120	1.15	.406	9.7	.0297	.9703	4.763		2.0385	.5094			
1600	150	1.30 + .12	.467	11.6	.0316	.9684	4.754		2.0347	.5085			
1636	186	1.42	.508	13.7	.0337	.9663	4.744		2.0304	.5074			
1700	210	1.50	.534	15.1	.0351	.9649	4.737		2.0274	.5067			
1950	380	1.50	.534	16.3	.0363	.9637	4.731		2.0248	.5061			
2100	450	1.50	.534	16.9	.0369	.9631	4.728		2.0235	.5058			
2200	510	1.50	.534	17.0	.0370	.9630	4.727		2.0231	.5057			
0945	0	1.50 + .12	.534	1 - 19.6	.0396	.9604	4.715		2.0180 - 1	.5044	1.90	0	4.18
1000	15	1.50	.534	19.6	.0396	.9604	4.715	2.336	2.0180	.5044	2.56	.65	4.86
1015	30	1.56	.551	19.7	.0397	.9603	4.714		2.0175	.5043	3.00	.45	3.36
1030	45	1.58	.561	2 - 0.0	.0400	.9600	4.713		2.0171	.5042	3.54	.54	4.03
1045	60	1.61 + .16	.584	0.2	.0402	.9598	4.711	$\frac{1}{V_s}$: .4280	2.0163	.5040	4.19	.65	4.85
1100	75	1.75	.630	0.7	.0407	.9593	4.709		2.0154	.5038	4.65	.46	3.42
1116	91	1.90	.680	1.3	.0413	.9587	4.706		2.0141	.5035	5.20	.55	3.42
1130	105	2.05	.729	2.3	.0423	.9577	4.701		2.0120	.5029	5.75	.55	4.37
1145	120	2.15	.753	3.4	.0434	.9566	4.696		2.0048	.5024	6.22	.47	3.54
1200	135	2.25	.795	4.9	.0449	.9551	4.689		2.0068	.5016	6.73	.51	3.78
1215	150	2.35	.828	6.3	.0463	.9537	4.682		2.0038	.5009	7.22	.49	3.63
1230	165	2.45	.861	7.6	.0476	.9524	4.675		2.0009	.5002	7.73	.51	3.77
1300	195	2.65 + .20	.940	10.3	.0503	.9497	4.662		1.9953	.4988	8.72	.99	3.75
1330	225	2.85	1.007	12.8	.0528	.9472	4.650		1.9902	.4975	2.0 9.66	.94	3.57
1400	255	3.00	.057	14.8	.0549	.9451	4.639		1.9854	.4963	2.40	.90	3.31
1530	340	3.00	.057	15.3	.0553	.9447	4.638		1.9850	.4962	5.87	2.97	3.63
1630	500	3.00	.057	15.8	.0558	.9442	4.635		1.9837	.4958	7.67	1.80	3.30
1830	600	3.00	.057										

TEST No 3 (CONT) 2

TIME	Δt	LOAD·PSI	LOAD·TSF	DIAL	DIAL·IN.	HT.	V	V_s	$e = V/V_s - 1$	$n = e/(1+e)$	PERM. GAGE	ΔQ	K·1/sec $\times 10^{-6}$
1005	0	3.0 +2.0	1.057	2-19.1	.0591	.9409	4.619		1.9769 - 1	.4941	0.59	0	3.10
1020	15	3.1	1.089	19.2	.0592	.9408	4.618	2.336	1.9765	.4940	0.94	.40	2.92
1035	30	3.4	1.189	19.9	.0599	.9401	4.615		1.9752	.4937	1.43	.37	2.71
1050	45	3.65 +.25	1.287	3-1.9	.0619	.9381	4.605		1.9709	.4926	1.81	.39	2.84
1105	60	3.9	1.370	4.2	.0642	.9358	4.594	$\frac{1}{V_s}$ = .4280	1.9662	.4914	2.17	.36	2.62
1120	75	4.15	1.452	6.1	.0661	.9339	4.584		1.9619	.4902	2.52	.37	2.69
1135	90	4.35	1.518	8.1	.0681	.9319	4.575		1.9581	.4893	2.87	.35	2.54
1150	105	4.65	1.618	10.0	.0700	.9300	4.565		1.9538	.4881	3.25	38	2.74
1205	120	4.8 +.28	1.680	11.5	.0715	.9285	4.558		1.9508	.4873	3.58	.33	2.28
1220	135	5.0	1.743	13.0	.0730	.9270	4.551		1.9478	.4866	3.93	.35	2.52
1235	150	5.15	1.793	14.6	.0746	.9254	4.543		1.9444	.4857	4.29	.36	2.59
1300	175	5.4	1.875	16.8	.0768	.9232	4.532		1.9396	.4844	4.89	.60	4.31
1315	190	5.6	1.940	18.0	.0780	.9220	4.526		1.9371	.4837	5.22	.33	2.27
1330	205	5.75	1.941	19.2	.0792	.9208	4.520		1.9345	.4830	5.60	.42	3.01
1345	220	5.90 +.32	2.052	4-0.2	.0802	.9198	4.515		1.9324	.4825	5.96	.36	2.57
1354	229	6.0	2.085	0.8	.0808	.9192	4.512		1.9311	.4821	6.00	.04	4.00
1505	300	6.0	2.085	1.9	.0819	.9181	4.507		1.9289	.4815	7.98	1.98	2.93
1530	325	6.0	2.085	2.0	.0821	.9179	4.506		1.9286	.4814	8.56	.57	2.25
1550	345	6.0	2.085	2.2	.0822	.9178	4.505		1.9281	.4813	.76	.46	2.21
1620	375	6.0	2.085	2.3	.0823	.9177	4.505		1.9281	.4813	1.36	.60	2.14
1705	420	6.0	2.085	2.6	.0826	.9174	4.503		1.9272	.4811	2.38	1.02	2.52
1710	0	6.0 +.32	2.085	4-2.7	.0827	.9173	4.503		1.9272-1	.4811	2.14	0	2.31
1715	5	6.1	2.120	2.7	.0827	.9173	4.503	2.336	1.9272	.4811	2.23	.04	1.93
1735	25	6.4	2.218	3.4	.0834	.9166	4.500		1.9260	.4807	2.72	.44	2.34
1745	35	6.6	2.285	4.2	.0842	.9158	4.496		1.9242	.4803	2.94	.22	2.35
1800	50	6.9	2.385	5.8	.0858	.9142	4.488	$\frac{1}{V_s}$ = .4280	1.9208	.4793	3.25	.31	2.38
1855	105	7.8 +.36	2.692	10.7	.0907	.9093	4.464		1.9105	.4765	4.40	1.15	2.68
1915	125	8.0	2.760	12.0	.0920	.9080	4.457		1.9075	.4757	4.82	.42	2.25
1930	140	8.15	2.810	13.0	.0930	.9070	4.452		1.9054	.4751	5.20	.38	2.70
1945	155	8.30	2.855	14.0	.0940	.9060	4.447		1.9033	.4745	5.47	.27	1.90
2000	170	8.50	2.925	14.8	.0948	.9052	4.443		1.9016	.4741	5.79	.32	2.25
2015	180	8.65	2.972	15.6	.0956	.9044	4.440		1.9003	.4737	6.11	.32	2.25
2030	200	8.85	3.040	16.5	.0965	.9035	4.435		1.8981	.4731	6.43	.32	2.25
2045	215	9.05	3.105	17.4	.0974	.9026	4.431		1.8964	.4726	6.74	.31	2.18
2100	230	9.20	3.155	18.3	.0983	.9017	4.426		1.8943	.4721	7.07	.33	2.21
2125	255	9.45	3.238	19.5	.0995	.9005	4.420		1.8917	.4713	7.59	.52	2.19
2130	260	9.50	3.258	19.7	.0997	.9003	4.419		1.8913	.4712	7.69	.10	2.10
2145	275	9.65	3.315	5-0.4	.1004	.8996	4.416		1.8900	.4708	8.01	.32	2.24
2200	290	9.80	3.365	0.9	.1009	.8991	4.414		1.8891	.4706	8.32	.31	2.17
2215	305	9.95	3.415	1.5	.1015	.8985	4.411		1.8879	.4705	8.63 0.53	.31	2.16
2230	320	10.10	3.465	2.1	.1021	.8979	4.408		1.8866	.4694	.90	.37	2.68
2245	335	10.25	3.513	2.7	.1027	.8973	4.405		1.8850	.4694	1.20	.30	2.09
2300	350	10.35	3.548	3.3	.1033	.8967	4.402		1.8840	.4692	1.41	.27	1.88
2315	365	10.50	3.595	4.0	.1040	.8960	4.398		1.8823	.4687	1.75	.28	1.95
2330	380	10.65	3.648	4.7	.1047	.8953	4.395		1.8810	.4683	2.02	.28	1.95
2345	395	10.85	3.710	5.3	.1053	.8947	4.392		1.8797	.4680	2.30	.28	1.95
2400	410	11.00	3.765	6.0	.1060	.8940	4.388		1.8780	.4675	2.57	.27	1.88
0015	425	11.20	3.830	6.6	.1066	.8936	4.387		1.8776	.4674	2.85	.28	1.95
0030	440	11.40	3.893	7.3	.1073	.8927	4.382		1.8754	.4667	3.12	.27	1.87
0045	455	11.55	3.943	7.8	.1078	.8922	4.380		1.8746	.4665	3.40	.28	1.94
0106	470	11.55	3.943	8.4	.1084	.8916	4.377		1.8733	.4661	3.67	.27	1.87

TEST No. 3 (CONT) 3

TIME	Δt	LOAD-PSI	LOAD TSF	DIAL	DIAL·IN	HT.	V	V_s	$e = V/V_s - 1$	$n = e/(1+e)$	PERM. GAGE	ΔQ·cc	$K \cdot {}'/sec \times 10^{-6}$
0850	0	11.55 +.45	3.960	5-10.8	.1108	.8892	4.365		1.8682 -1	.4647	0.48	0	1.87
0905	15	11.95	4.090	11.0	.1110	.8840	4.364	2.336	1.8677	.4646	.75	.27	1.86
0920	30	12.45	4.260	11.5	.1115	.8885	4.362		1.8669	.4644	1.01	.26	1.81
0935	45	12.90	4.405	12.4	.1124	.8876	4.357		1.8647	.4637	1.26	.25	1.73
0950	60	13.40	4.570	13.7	.1137	.8863	4.351	$\frac{1}{V_s} = .4280$	1.8622	.4631	1.50	.24	1.66
1005	75	13.85	4.735	15.3	.1153	.8847	4.343		1.8588	.4620	1.72	.22	1.52
1022	92	14.3	4.870	16.9	.1169	.8831	4.335		1.8553	.4610	1.95	.23	1.40
1035	105	14.7	5.000	18.0	.1180	.8820	4.330		1.8532	.4603	2.16	.21	1.66
1050	120	15.1	5.130	19.2	.1192	.8808	4.324		1.8506	.4596	2.37	.21	1.45
1105	135	15.5 + .48	5.275	6-0.4	.1204	.8796	4.318		1.8481	.4589	2.59	.22	1.50
1120	150	15.9	5.405	1.5	.1215	.8785	4.312		1.8455	.4581	2.81	.22	1.50
1135	165	16.3	5.535	2.6	.1226	.8774	4.307		1.8433	.4574	3.03	22	1.50
1150	180	16.6	5.635	3.5	.1235	.8765	4.303		1.8416	4570	3.26	.23	1.56
1205	195	16.9	5.735	4.5	.1245	.8755	4.297		1.8391	.4562	3.49	23	1.66
1215	205	17.2	5.835	5.2	.1252	.8748	4.294		1.8378	.4558	3.64	.15	1.53
1305	255	18.5	6.260	8.5	.1285	.8715	4.278		1.8310	.4538	4.25	.61	1.52
1340	290	19.3 +.52	6.545	10.5	.1305	.8695	4.268		1.8267	.4525	4.85	.60	1.55
1400	310	19.75	6.640	11.6	.1316	.8684	4.263		1.8245	.4519	5.12	27	1.41
1416	326	20.1	6.800	12.4	.1324	.8676	4.259		1.8228	.4513	5.36	24	1.52
1430	340	20.4	6.900	13.0	.1330	.8670	4.256		1.8215	.4510	5.56	.20	1.45
1500	3.70	21.1	7.130	14.6	.1346	.8654	4.248		1.8181	.4499	5.98	.42	1.42
1515	3.85	21.4	7.230	15.2	.1352	.8648	4.245		1.8168	.4495	6.19	.21	1.42
1530	4.00	21.8	7.360	16.0	.1360	.8640	4.241		1.8151	.4490	6.39	.20	1.35
1547	417	22.15	7.480	16.8	.1368	.8632	4.237		1.8134	.4485	6.64	25	1.47
1600	430	22.4	7.560	17.4	.1374	.8626	4.234		1.8121	.4481	6.80	16	1.25
1615	445	22.8	7.700	18.2	.1382	.8618	4.230		1.8104	.4476	7.00	20	1.34
1630	460	23.15	7.815	18.9	.1389	.8611	4.227		1.8091	.4472	7.21	21	1.41
1645	475	23.5	7.925	19.6	.1396	.8604	4.223		1.8074	.4467	7.41	20	1.34
1700	490	23.85 +.57	8.025	7-0.4	.1404	.8596	4.219		1.8057	.4461	7.61	20	1.34
1950	660	23.40	8.080	2.3	.1423	.8577	4.210		1.8019	.4450	8.14		
2005	675	23.90	8.080	2.3	.1423	.8577	4.210		1.8019	.4450	8.35	21	1.41

SAMPLE DATA

SPECIFIC GRAVITY	2.59
INITIAL HEIGHT of SAMPLE	1.0000 IN
FINAL HEIGHT of SAMPLE	.8577 IN
CROSS SECTIONAL AREA	4.9087 IN^2
INITIAL MOISTURE CONTENT	40.5 %
FINAL MOISTURE CONTENT	31.75%
WT. of SOLIDS	99.148 Gr.
VOL. of SOLIDS	2.336 IN^3

APPENDIX D

RAW DATA

TEST NO. 4

TEST No. 4

1

TIME	Δt	PRESSURE	DIAL	DIAL·IN	HT.	VOL = V	V_s	$e = V/V_s - 1$	$n = e/(1+e)$	PERM GAGE	ΔQ·cc	K·ft/sec 10^{-6}
0900	0 SEC	0 TSF	0-000	0	1.0000	4.9087	2.3419	1.0960				
	5		0-19.0	.0190	.9810	4.8157		1.0563				
	10		1-4.0	.0240	.9760	4.7916		1.0460				
	20		1-6.0	.0260	.9740	4.7818	$\frac{1}{V_s} = .4270$	1.0418				
	30		1-7.2	.0272	.9738	4.7808		1.0414				
	40		1-9.6	.0296	.9714	4.7690		1.0363				
	50		1-11.3	.0313	.9687	4.7558		1.0307				
	1 MIN		1-12.0	.0320	.9674	4.7494		1.0279				
	1½		1-16.0	.0360	.9640	4.7327		1.0208				
	2		1-19.6	.0396	.9604	4.7150		1.0133				
	3	INSTANTANEOUS	2-4.9	.0449	.9551	4.6840		1.0022				
	4		2-8.6	.0486	.9514	4.6709		.9944				
0905	5		2-11.1	.0511	.9489	4.6586		.9892				
	10		2-15.6	.0556	.9444	4.6365		.9897				
	20		2-16.3	.0563	.9437	4.6331		.9783				
	30		2-16.6	.0566	.9434	4.6316		.9776				
1000	60		2-17.0	.0570	.9430	4.6296		.9768				
1100	120		3-0.5	.0605	.9395	4.6124		.9694				
1200	180		3-0.9	.0609	.9391	4.6105		.9686				
1300	240		3-1.3	.0613	.9387	4.6085		.9678				
1500	360		3-1.8	.0618	.9382	4.6061		.9668				
1700	480	1/2	3-2.1	.0621	.9379	4.6046		.9661				
1700	0 SEC	1/2	3-2.1	.0621	.9379	4.6046		.9661	.4913	3.0		
	5		3-13.7	.0737	.9263	4.5476		.9418	.4850			
	10		3-15.5	.0755	.9245	4.5388		.9380	.4840			
	15		3-16.6	.0766	.9234	4.5334		.9357	.4833			
	20		3-17.8	.0778	.9222	4.5275		.9332	.4827			
	30		3-19.9	.0799	.9201	4.5172		.9288	.4815			
	40		4-1.6	.0816	.9184	4.5089		.9253	.4806			
	50		4-2.9	.0829	.9171	4.5025		.9225	.4798			
	60		4-4.0	.0840	.9160	4.4971		.9202	.4792			
	1½ MIN		4-6.6	.0866	.9134	4.4843		.9147	.4777	2.46		
	2		4-8.3	.0883	.9117	4.4760		.9112	.4767	2.40		
	3		4-10.2	.0902	.9098	4.4666		.9072	.4756	2.37		
	4		4-11.1	.0911	.9089	4.4622		.9053	.4759	2.35		
	5		4-11.5	.0915	.9085	4.4603		.9045	.4749	2.37	.02	
	10		4-12.2	.0922	.9078	4.4568		.9030	.4745	2.50	.13	2.75
	20		4-12.6	.0926	.9074	4.4549		.9022	.4742	2.78	.28	2.96
	30		4-12.9	.0929	.9071	4.4534		.9016	.4741	3.09	.31	3.28
	45	INSTANTANEOUS	4-13.2	.0932	.9068	4.4519		.9009	.4739	3.56	.45	3.17
1800	60		4-13.3	.0933	.9067	4.4514		.9007	.4738	4.03	.47	3.31
	75		4-13.4	.0934	.9066	4.4509		.9005	.4738	4.52	.49	3.45
	90		4-13.5	.0935	.9065	4.4505		.9003	.4737	5.00	.48	3.38
	105		4-13.6	.0936	.9064	4.4500		.9001	.4737	5.48	.48	3.38
1900	120		4-13.7	.0937	.9063	4.4495		.8999	.4737	5.96	.48	3.38
	135		4-13.7	.0937	.9063	4.4495		.8999	.4737	6.45	.49	3.45
	150		4-13.8	.0938	.9062	4.4490		.8999	.4736	6.95	.51	3.59
	165		4-13.8	.0938	.9062	4.4490		.8997	.4736	7.45	.50	3.52
2000	180		4-13.9	.0939	.9061	4.4485		.8995	.4735	7.95	.50	3.52
	195		4-13.9	.0939	.9061	4.4485		.8995	.4735	8.45 0.7	.50	3.52
	210		4-14.0	.0940	.9060	4.4480		.8992	.4734	1.21	.51	3.58
	225		4-14.0	.0940	.9060	4.4480		.8992	.4734	1.64	.43	3.11
2100	240		4-14.0	.0940	.9060	4.4480		.8992	.4734	2.09	.45	3.7
	255		4-14.1	.0941	.9059	4.4475		.8990	.4734	2.54	.45	3.17
	270		4-14.1	.0941	.9059	4.4475		.8990	.4734	2.99	.45	3.17
	285		4-14.1	.0941	.9059	4.4475		.8990	.4734	3.46	.47	3.31
2200	300	1.0	4-14.1	.0941	.9059	4.4475		.8990	.4734	3.97	.46	3.24

TEST NO. 4 (CONT.) 2

TIME	Δt	PRESSURE	DIAL	HT.	DIAL IN.	VOL: V	V_s	e: V/V_s-1	n: $e/1+e$	PERM. GAGE	ΔQ-cc	K·ft/sec 10^{-6}	
0730	0 sec	1.0	4-16.4	.9036	.0964	4.4362	2.3419	.8942	.4720	3.48		3.24	
	5	↓	5-0.8	.8992	.1008	4.4146		.8850	.4694				
	10		5-1.8	.8982	.1018	4.4097	$\frac{1}{V_s}$ = .4270	.8829	.4689	3.35			
	20		5-3.0	.8970	.1030	4.4038		.8804	.4681	3.32			
	30		5-4.2	.8958	.1042	4.3979		.8779	.4674	3.30			
	40		5-5.1	.8949	.1051	4.3935		.8766	.4669	3.27			
	50		5-5.6	.8944	.1056	4.3911		.8749	.4666	3.26			
	60		5-6.2	.8938	.1062	4.3881		.8737	.4662	3.25			
	1½ MIN		5-7.2	.8928	.1072	4.3832		.8716	.4656	3.23			
	2		5-7.8	.8922	.1078	4.3847		.8716	.4656	3.22			
	3		5-8.5	.8915	.1085	4.3768		.8688	.4648	3.23	.01		
	4		5-8.9	.8911	.1089	4.3749		.8680	.4646	3.24	.01		
	5		5-9.1	.8909	.1091	4.3739		.8676	.4645	3.25	.01		
	10		5-9.6	.8904	.1096	4.3714		.8665	.4642	3.37	.13	2.49	
	20		5-10.1	.8899	.1101	4.3690		.8655	.4639	3.64	.27	2.80	
	30		5-10.4	.8896	.1104	4.3675		.8649	.4637	3.92	.28	2.90	
	45	INSTANTANEOUS	5-10.7	.8893	.1107	4.3660		.8642	.4635	4.33	.41	2.83	
0830	60		5-10.9	.8891	.1109	4.3650		.8638	.4634	4.74	.41	2.83	
	75		5-11.0	.8890	.1110	4.3645		.8636	.4634	5.17	.43	2.96	
	90		5-11.1	.8889	.1111	4.3641		.8634	.4633	5.60	.43	2.96	
0930	120		5-11.2	.8888	.1112	4.3636		.8632	.4632	6.03	.43	2.96	
	135		5-11.3	.8887	.1113	4.3631		.8630	.4632	6.46	.43	2.96	
	150		5-11.4	.8886	.1114	4.3626		.8628	.4630	6.89	.43	2.96	
	165		5-11.5	.8885	.1115	4.3621		.8625	.4630	7.32	.43	2.96	
1030	180		5-11.6	.8884	.1116	4.3616		.8623	.4630	8.19 1.55	.87	3.01	
	195		5-11.7	.8883	.1117	4.3611		.8621	.4629	2.00	.45	3.10	
	210		5-11.8	.8882	.1118	4.3606		.8619	.4629	2.41	.41	2.83	
	225		5-11.8	.8882	.1118	4.3606		.8619	.4629	2.75	.34	2.34	
1130	240		5-11.9	.8881	.1119	4.3601		.8617	.4628	3.16	.41	2.83	
	255		5-11.9	.8881	.1119	4.3601		.8617	.4628	3.58	.42	2.90	
1200	270		5-11.9	.8881	.1119	4.3601		.8617	.4628	4.00	.42	2.90	
	285	↓	5-11.9	.8881	.1119	4.3601		.8617	.4628	4.42	.42	2.90	
	315		5-12.0	.8880	.1120	4.3596		.8615	.4627	5.27	.85	2.93	
1300	330	1.50	5-12.0	.8880	.1120	4.3596		.8615	.4627	5.68	.41	2.83	
1400	0	1.50	5-12.2	.8878	.1122	4.3587		.8612	.4627	7.42		2.83	
	5	↓	5-14.0	.8860	.1140	4.3498		.8573	.4615	7.40			
	10		5-14.6	.8854	.1146	4.3469		.8561	.4612				
	15		5-15.3	.8847	.1153	4.3434		.8546	.4608				
	20		5-15.6	.8844	.1156	4.3420		.8540	.4606	7.31			
	30		5-16.4	.8836	.1164	4.3380		.8523	.4601	7.28			
	40		5-17.0	.8830	.1170	4.3351		.8510	.4597	7.27			
	50		5-17.3	.8827	.1173	4.3336		.8504	.4595	7.27			
	60	INSTANTANEOUS	5-17.6	.8824	.1176	4.3321		.8498	.4594	7.25			
	1½		5-18.3	.8817	.1183	4.3287		.8483	.4589	7.26	.01		
	2		5-18.8	.8812	.1188	4.3263		.8473	.4586	7.27	.01		
	3		5-19.2	.8808	.1192	4.3243		.8464	.4584	7.28	.01		
	4		5-19.5	.8805	.1195	4.3228		.8458	.4582	7.29	.01		
	5		5-19.8	.8802	.1198	4.3213		.8451	.4580	7.30	.01		
	10		6-0.3	.8797	.1203	4.3199		.8445	.4578	7.42	.12	2.46	
	20		6-0.8	.8792	.1208	4.3164		.8431	.4574	7.68	.24	2.66	
	30		6-1.1	.8789	.1211	4.3150		.8425	.4572	7.94	.26	2.66	
	45		6-1.4	.8786	.1214	4.3135		.8418	.4570	8.33 1.85	.39	2.66	
1500	60		6-1.6	.8784	.1216	4.3125		.8414	.4569	2.22	.37	2.52	
	75		6-1.8	.8782	.1218	4.3115		.8410	.4568	2.60	.38	2.64	
	90	↓	6-1.9	.8781	.1219	4.3111		.8408	.4567	2.97	.37	2.52	

TEST No. 4. (CONT.) 3

TIME	Δt	PRESSURE	DIAL	DIAL·IN	HT.	VOL.: V	Vs	e: V/Vs - 1	n: e/1+e	PERM. GAGE	ΔQ · cc	K · FT/SEC · 10⁻⁶	
1545	105		6-2.0	.1220	.8780	4.3106	2.3419	1.8406	.4566	3.36	.39	2.66	
1615	120		2.1	.1221	.8779	4.3101		1.8404	.4566	4.13	.77	2.60	
1630	135		2.2	.1222	.8778	4.3096		1.8401	.4565	4.52	.39	2.63	
1645	150	INST.	2.3	.1223	.8777	4.3041	$\frac{1}{V_s}$ = .4270	1.8399	.4565	4.91	.39	2.63	
1700	180		2.4	.1224	.8776	4.3086		1.8397	.4564	5.31	.40	2.72	
1715	195		2.4	.1224	.8776	4.3086		1.8397	.4564	5.71 .58	.40	2.72	
1830	270		2.6	.1226	.8774	4.3076		1.8393	.4564	2.45	1.87	2.55	
1845	285		2.7	.1227	.8773	4.3071		1.8393	.4563	2.82	.37	2.52	
1900	300		2.7	.1227	.8773	4.3071		1.8393	.4563	3.20	.38	2.59	
1915	315		2.7	.1227	.8773	4.3071		1.8391	.4563	3.59	.39	2.66	
1930	330		2.8	.1228	.8772	4.3066		1.8391	.4561	3.97	.37	2.52	
2000	360	2.00	2.8	.1228	.8772	4.3066		1.8389	.4561	4.75	.78	2.66	
0845	0 SEC	2.00	6-4.5	.1245	.8745	4.2934		1.8332-1	.4545	2.74		2.50	
	5	INSTANTANEOUS	5.8	.1258	.8742	4.2919		1.8326	.4543				
	10		6.3	.1263	.8737	4.2894		1.8315	.4539				
	15		6.5	.1265	.8735	4.2885		1.8311	.4538				
	20		6.8	.1268	.8734	4.2880		1.8309	.4538	2.68			
	30		7.2	.1272	.8728	4.2850		1.8296	.4534	2.67			
	40		7.6	.1276	.8724	4.2831		1.8288	.4531	2.67			
	50		7.8	.1278	.8722	4.2821		1.8284	.4530	2.67			
	60		7.9	.1279	.8721	4.2816		1.8282	.4530	2.67			
	1 1/2 MIN		8.3	.1283	.8717	4.2796		1.8273	.4527	2.67			
	2		8.6	.1286	.8714	4.2781		1.8267	.4525	2.67			
	3		9.0	.1290	.8710	4.2762		1.8261	.4523	2.68	.01		
	4		9.2	.1292	.8708	4.2752		1.8255	.4522	2.70	.02		
	5		9.4	.1294	.8706	4.2942		1.8250	.4520	2.72	.02		
	10		9.8	.1298	.8702	4.2723		1.8242	.4518	2.83	.10	2.02	
	20		10.3	.1303	.8697	4.2698		1.8232	.4515	3.05	.23	2.33	
0915	30		10.6	.1306	.8694	4.2683		1.8225	.4513	3.28	.23	2.32	
	45		10.8	.1308	.8692	4.2673		1.8221	.4511	3.63	.35	2.36	
	65		11.2	.1312	.8688	4.2654		1.8213	.4509	4.10	.47	2.38	
	75		11.2	.1312	.8688	4.2654		1.8213	.4509	4.34	.24	2.43	
1015	90		11.3	.1313	.8687	4.2649		1.8211	.4508	4.68	.34	2.29	
	105		11.4	.1314	.8686	4.2644		1.8208	.4507	5.05	.37	2.50	
1045	120		11.5	.1315	.8685	4.2639		1.8206	.4507	5.42	.37	2.50	
	135		11.6	.1316	.8684	4.2634		1.8204	.4506	5.79	.37	2.50	
	150		11.7	.1317	.8683	4.2629		1.8202	.4506	6.16	.37	2.50	
1145	180		11.8	.1318	.8682	4.2624		1.8200	.4505	6.92	.76	2.56	
	195		11.9	.1319	.8681	4.2620		1.8198	.4504	0.22		2.02	
	210		12.0	.1320	.8680	4.2615		1.8196	.4504	.54	.32	2.16	
	225		12.0	.1320	.8680	4.2615		1.8196	.4504	.91	.37	2.50	
1245	240		12.0	.1320	.8680	4.2615		1.8196	.4504	1.26	.35	2.36	
	255		12.1	.1321	.8679	4.2610		1.8194	.4503	1.60	.34	2.29	
	285		12.1	.1321	.8679	4.2610		1.8194	.4503	2.39	.79	2.66	
1400	315	2.50	12.1	.1321	.8679	4.2610		1.8194	.4503	3.00	.61	2.24	
1405	0 SEC	2.50	6-12.2	.1322	.8678	4.2605		.8192	.4503	3.12			
	5	INST.	13.4	.1334	.8666	4.2546		.8167	.4495				
	10		13.8	.1338	.8662	4.2526		.8158	.4492	3.08			
	15		14.1	.1341	.8659	4.2511		.8152	.4490				
	20		14.3	.1343	.8657	4.2502		.8148	.4489				
	30		14.8	.1348	.8652	4.2477		.8137	.4486	3.07			
	40		15.2	.1352	.8648	4.2457		.8129	.4483	3.06			
	50		15.4	.1354	.8646	4.2448		.8125	.4482	3.06			
	60		15.5	.1355	.8645	4.2445		.8124	.4482	3.06			
	1 1/2 MIN		16.0	.1360	.8640	4.2418		.8112	.4478	3.06			
1407	2		16.3	.1363	.8637	4.2403		.8106	.4476	3.06			

TEST No 4 (CONT) 4

Time	Δt	Pressure	DIAL	DIAL-IN	HT	VOL	Vs	e = V/Vs - 1	n = e/(e+1)	Perm. GAGE	ΔQ · cc	K · ft/sec × 10^-6	
	3		6-16.6	.1366	.8634	4.2389	2.3414	.8100	.4475	3.06	0		
	4		16.8	.1368	.8632	4.2379		.8095	.4473	3.08	.02		
	5		17.0	.1370	.8630	4.2364		.8091	.4472	3.10	.02		
	10		17.5	.1375	.8625	4.2345	1/Vs = .4270	.8081	.4469	3.14	.09	1.81	
	15		17.8	.1378	.8622	4.2330		.8074	.4467	3.28	.09	1.81	
	20		18.0	.1380	.8620	4.2320		.8070	.4465	3.39	.11	2.20	
	30		18.3	.1383	.8617	4.2305		.8064	.4464	3.61	.22	2.20	
	45		18.7	.1387	.8613	4.2286		.8065	.4461	3.95	.34	2.22	
1505	60		18.8	.1388	.8612	4.2281		.8053	.4460	4.29	.34	2.27	
	75		19.0	.1390	.8610	4.2271		.8049	.4459	4.63	.34	2.27	
	90		19.2	.1392	.8608	4.2261		.8045	.4458	4.98	.35	2.34	
	110		19.2	.1392	.8608	4.2261		.8045	.4458	5.42	.44	2.20	
1605	120		19.3	.1393	.8607	4.2256		.8043	.4457	5.66	.24	2.41	
	135		19.3	.1393	.8607	4.2256		.8043	.4457	6.00	.34	2.27	
	160		19.5	.1395	.8605	4.2246		.8039	.4456	6.59	.59	2.36	
	165		19.5	.1395	.8605	4.2246		.8039	.4456	6.73	.14	2.80	
1705	180		19.6	.1396	.8604	4.2241		.8036	.4455	7.07	.34	2.27	
	195		19.6	.1396	.8604	4.2241		.8036	.4455	7.43 1.60	.36	2.40	
	265		19.9	.1399	.8601	4.2227		.8030	.4453	3.09	1.49	2.13	
	280		19.9	.1399	.8601	4.2227		.8030	.4453	3.43	.34	2.27	
1900	295		7-.00	.1400	.8600	4.2222		.8028	.4453	3.76	.33	2.21	
	310		-0.0	.1400	.8600	4.2222		.8028	.4453	4.10	.34	2.27	
	325		0.0	.1400	.8600	4.2222		.8028	.4453	4.44	.34	2.27	
	340		0.0	.1400	.8600	4.2222		.8028	.4453	4.78	.34	2.27	
2000	355	3.00	0.0	.1400	.8600	4.2222		.8028	.4453	5.12	.34	2.27	
0845	1125		7-2.4	.1424	.8676	4.2104		.7978	.4437			2.19	
						C		Vol					
1415	0 sec	3.00	7-2.8	.1428	.8572	1.7970		4.2084	.4435	6.49		2.19	
	5		-3.3	.1433	.8567	1.7959		4.2066	.4431				
	10		3.4	.1434	.8566	1.7957		4.2055	.4431	6.48			
	15		3.5	.1435	.8565	1.7955		4.2050	.4430				
	20		3.6	.1436	.8564	1.7953		4.2045	.4429	6.48			
	30		3.7	.1437	.8563	1.7951		4.2040	.4429	6.47			
	40		3.8	.1438	.8562	1.7948		4.2035	.4428	6.48			
	50		3.8	.1438	.8562	1.7948		4.2035	.4428	6.48			
	60		3.9	.1439	.8561	1.7946		4.2030	.4427	6.48			
	1 1/2 MIN		4.0	.1440	.8560	1.7944		4.2025	.4427	6.49			
	2		4.1	.1441	.8559	1.7942		4.2021	.4426	6.50			
	3		4.2	.1442	.8558	1.7940		4.2016	.4425	6.51			
	4		4.3	.1443	.8557	1.7938		4.2011	.4425	6.53			
	5		4.4	.1444	.8556	1.7936		4.2006	.4424	6.56			
	10		4.8	.1448	.8552	1.7928		4.1986	.4422	6.65	10	1.99	
	15		5.0	.1450	.8550	1.7923		4.1976	.4420	6.75	.10	1.99	
	20		5.1	.1451	.8549	1.7921		4.1971	.4419	6.85	.10	1.99	
	30		5.3	.1453	.8547	1.7917		4.1962	.4418	7.07	.22	2.18	
	45		5.5	.1455	.8545	1.7915		4.1952	.4418	7.40	.33	2.18	
1515	60		5.7	.1457	.8543	1.7909		4.1942	.4416	7.73	.33	2.18	
	75		5.8	.1458	.8542	1.7907		4.1937	.4415	8.06	.33	2.18	
	90			.				4.	.				
	105		6.1	.1460	.8539	1.7900		4.1922	.4413	8.69 1.70	.63	2.09	
	120		6.2	.1462	.8538	1.7898		4.1917	.4412	2.00	.30	1.98	
	135		6.2	.1462	.8538	1.7898		4.1917	.4412	2.31	.31	2.05	
1745	150		6.3	.1463	.8537	1.7896		4.1913	.4412	2.66	.29	2.01	
	165		6.3	.1463	.8537	1.7896		4.1913	.4412	2.92	.32	2.01	
	225		6.5	.1465	.8535	1.7891		4.1903	.4410	4.15	1.23	2.04	
1845	270		6.6	.1466	.8534	1.7890		4.1890	.4410	5.14	.94	2.18	

TEST No 4												5
TIME	Δt	Pressure	DIAL	DIAL-IN	HT	VOL	V_s	$e = V/V_s - 1$	$n = e/(1+e)$	PERM. GAGE	ΔQ - cc	K-ft/sec $\times 10^{-6}$
1900	285	↓	7-6.7	.1467	.8533	4.1893	2.3419	.7888	.4409	5.45	.31	2.05
1915	300		6.7	.1467	.8533	4.1893		.7888	.4409	5.78	.33	2.19
	315		6.7	.1467	.8533	4.1893		.7888	.4409	6.07	.29	1.92
	330		6.8	.1468	.8532	4.1888	$\frac{1}{V_s} = .4270$	.7886	.4409	6.41	.34	2.25
	345		6.8	.1468	.8532	4.1888		.7886	.4409	6.74	.33	2.19
2015	360		6.8	.1468	.8532	4.1888		.7886	.4409	7.06	.32	2.11
	375		6.8	.1468	.8532	4.1888		.7886	.4409	7.39	.33	2.11
	390		6.9	.1469	.8531	4.1883		.7884	.4408	7.71	.32	2.11
	405		6.9	.1469	.8531	4.1883		.7884	.4408	8.03	.32	2.11
2115	420		7.0	.1470	.8530	4.1878		.7882	.4407	8.38	.35	2.32
	435		7.0	.1470	.8530	4.1878		.7882	.4407	8.70	.32	2.11
0900		3.50	8.0	.1480	.8520	4.1878		.7860	.4400			1.92
0900	0 sec	3 50	7.80	.1480	.8520	4 1829		.7860	.4400	362		
	5		8.7	.1487	.8513	4 1795		.7846	.4396			
	10		89	.1489	.8511	" 1785		.7842	.4395			
	15		9.0	.1490	.8510	" 1780		.7840	.4394	[illegible]62		
	20		91	.1491	.8509	" 1775		7837	.4393	361		
	30		92	.1472	.8508	" 1770		.7835	4393	361		
	40		93	.1493	.8507	4 1765		7833	.4392	3[illegible]1		
	50		9.4	.1494	.8506	" 1761		.7831	.4391	[illegible]		
	60		9.5	.1495	.8505	".1756		7829	.4391	[illegible]		
	1½ Min		9.6	.1496	.8504	" 1751		7827	.4390	311	01	
	2		98	.1498	.8502	" 1741		7823	4389	31[illegible]	01	
	3		10.0	.1500	.8500	" 1731		.7819	.4388	314	01	
	4		10.1	.1501	.8499	" 1721		7814	4386	365	01	
	5		102	.1502	8498	" 1716		.7812	438[illegible]	[illegible]7	07	
	10		106	1506	.8494	4 1697		.7804	.4383	[illegible]	[illegible]1	178
	20		11.0	.1510	.8490	4 1677		.7796	.4380	[illegible]	19	1[illegible]7
	30		113	.1513	.8487	4 1662		.7790	4379	414	.19	187
	45		11.5	.1515	8485	4 1652		.7785	.43[illegible]8	41[illegible]	2[illegible]	1[illegible]4
1000	60		117	.1517	.8483	4 1643		.7781	.4376	412	21	184
	80		11.9	1519	.8481	4 1633		.7777	.4374	512	50	246
	90		12.0	.1520	.8480	4 1628		.7775	.4374	537	2[illegible]	1[illegible]
	105		121	.1521	.8479	4.1623		.7773	.4373	5[illegible]6	.28	1[illegible]4
1100	120		122	.1522	.8478	4 1618		.7770	.4372	5[illegible]	.20	197
	135		123	.1523	.8477	4 1613		77[illegible]	.4371	62[illegible]	.30	197
	150		124	.1524	.8476	4 1608		7766	4371	6[illegible]	.30	197
	165		125	.1525	.8475	4 1603		7764	.437[illegible]	683	.3[illegible]	1.97
1200	180		125	1526	.8475	4 1603		.7764	.4370	712	.21	216
	195		126	.1526	.8474	4 1598		.7762	.4370	742	.3[illegible]	192
	210		127	.1527	.8473	4 1593		7760	.[illegible]364	772	[illegible]	197
	225		128	.1528	.8472	4 1589		.7758	.4361	8[illegible]2	.30	197
1300	240		128	.1528	.8472	4 1591		.7758	4361	8[illegible]2	.3[illegible]	197
	255		129	.1529	.847[illegible]	4 1584		.7757	43[illegible]	412	.3[illegible]	[illegible]97
	270		129	1529	.8471	4 1584		.7756	.4365	432 1[illegible]	.10	197
	285		130	153[illegible]	.847[illegible]	4 1574		7751	43[illegible]	21[illegible]	28	184
1400	300		130	.153[illegible]	.847[illegible]	4.1579		77[illegible]4	.4[illegible]	24[illegible]	.27	177
	330	↓	131	.1531	.8469	4 1574		.7752	43[illegible]	364	.54	194
1500	360	4 00	132	.1532	.8466	4 1561		.7719	[illegible]	3[illegible]	.54	177

TEST No 4

6

TIME	Δt	PRESSURE	DIAL	DIAL-IN	HT	VOL	Ys	e = V/Vs - 1	n = e/1+e	PERM-GAGE	ΔQ-cc	K-ft/sec×10^{-4}	
1500	0	4.00	7-13.2	.1532	.8468	4.1561		.7749	.4365	3.64			
	5		13.6	.1536	.8464	4.1550	2.3419	.7741	.4363				
	10		13.8	.1538	.8462	4.1540		.7737	.4362				
	15		13.8	.1538	.8462	4.1540		.7737	.4362				
	20		13.9	.1539	.8461	4.1535	$\frac{1}{Y_s} = .4270$	.7733	.4361	3.63			
	30		14.0	.1540	.8460	4.1530		.7733	.4360	3.63			
	40		14.1	.1541	.8460	4.1525		.7731	.4360	3.63			
	50		14.1	.1541	.8459	4.1525		.7731	.4360	3.[illegible]7			
	60 sec		14.2	.1542	.8458	4.1520		.7728	.4359	3.63			
	1½ MIN		14.3	.1543	.8457	4.1515		.7726	.4358	3.64			
	2		14.4	.1544	.8456	4.1510		.7724	.4357	[illegible]			
	3		14.5	.1545	.845[illegible]	4.1505		.7722	.4357	3.65			
	4		14.6	.1546	.8454	4.1500		.7720	.4356	3.66			
	5		14.7	.1547	.8453	4.1495		.7718	.4356	3.67			
	10		15.1	.1551	.8449	4.1476		.7710	.4353	[illegible]	[illegible]	1.77	
	20		15.4	.1554	.8446	4.1461		.7703	.4351	[illegible].94	[illegible]	1.77	
	30		15.6	.1556	.8444	4.1451		[illegible]	.4349	4.13	19	1.8[illegible]	
1600	45		15.9	.1557	.8441	4.1436		.7643	.4348	4.41	[illegible]	[illegible]	
	60		16.1	.1561	[illegible]	4.1427		[illegible]	.434[illegible]	4.70	21	1.81	
	75		16.2	.1562	.8438	4.1422		.768[illegible]	.4346	4.97	29	[illegible]	
	90		16.3	.1563	.8437	4.1417		[illegible]	.4345	5.28	[illegible]	[illegible]	
	105		16.5	.1565	.8435	4.1407		[illegible]	.4343	5.[illegible]7	[illegible]	1.8[illegible]	
1700	120		16.6	.1566	.843[illegible]	4.1407		[illegible]	.4343	[illegible]	29	[illegible]	
	135		16.6	.1566	.8434	4.1402		[illegible]	.4342	6.1[illegible]	21	1.8[illegible]	
1730	150		16.7	.1567	.8433	4.1397		.7676	.4342	6.44	.20	1.8[illegible]	
1900	240		17.1	.1571	.8429	4.1377		.7667	.4339	8.[illegible]3	.29	[illegible]	
	255		17.1	.1571	.84[illegible]9	4.1377		.7667	[illegible]	8.[illegible]3	3[illegible]	1.[illegible]	
	270		17.2	.1572	.8428	4.1373		.76[illegible]	.4339	8.[illegible]3 1.79	3[illegible]	[illegible]	
	285		17.2	.1572	.8428	4.1373		[illegible]	.4339	2.[illegible]	24	1.[illegible]	
2000	300		17.2	.1572	.8428	4.1373		[illegible]	.4339	[illegible]	.28	[illegible]	
	315		17.2	.1572	.8428	4.1373		.7666	.4339	2.[illegible]0	27	1.76	
	330		17.3	.1573	.8427	4.13[illegible]8		.7664	.4338	2.68	[illegible]	1.8[illegible]	
	345		17.3	.1573	.8427	4.1368		.76[illegible]	.4338	[illegible]7	[illegible]	1.8[illegible]	
2100	360		17.3	.1573	.8427	4.[illegible]		.7664	.4338	2.44	27	1.76	
	380		17.3	.1573	.8427	4.1369		.7664	.4338	3.82	38	[illegible].4[illegible]	
2130	390		17.3	.1573	.8427	4.1365		.7664	.4336	[illegible]	29	1.5[illegible]	
1000		4.50	18.6	.1586	.8414	4.130[illegible]		.7636	.4324			1.73	
1000	0	4.50	7-18.6	.1586	.8414	4.1304		.7636	.4329	3.85			
	5		19.3	.1593	.8407	4.1269		.7621	.4324	3.84			
	10		19.4	.1594	.8406	4.1265		.7620	.4324	3.84			
	15		19.5	.1595	.8405	4.1260		.7617	.4323	3.84			
	20		19.6	.1596	.8404	4.1255		.7615	.4323	3.84			
	30		19.7	.1597	.8403	4.1251		.7613	.4322	3.84			
	40		19.8	.1598	.8402	4.1245		.7611	.4321	3.84			
	50		19.8	.1598	.8402	4.1245		.7611	.4321	3.84			
	60		19.9	.1599	.8401	4.1240		.7604	.4321	3.84			
	1½ MIN		8-0.00	.1600	.8400	4.1235		.7606	.4320	3.85	.01		
	2		0.1	.1601	.8399	4.1230		.7604	.4319	3.86	.01		
	3		0.2	.1602	.8398	4.1225		.7602	.4318	3.87	.01		
	4		0.3	.1603	.8397	4.1220		.7600	.4316	3.[illegible]4	.0[illegible]		
	5		0.4	.1604	.8396	4.1215		.759[illegible]	.4317	3.91	.02		
	10		0.7	.1607	.8393	4.1201		.7592	.431[illegible]	3.94	16	1.75	
	20		1.0	.1610	.8390	4.1186		.7586	.4312	4.16	.17	1.65	
1030	30		1.3	.1613	.8387	4.1171		.7580	.4311	4.[illegible]	[illegible]	1.76	
	45		1.5	.1615	.8385	4.1161		.757[illegible]	.43[illegible]	4.[illegible]2	[illegible]	1.42	
1130	90		1.9	.1619	.8381	4.1142		.7567	.43[illegible]7	5.[illegible]1	[illegible]2	1.77	

TEST No 4

7

TIME	Δt	Pressure	DIAL	DIAL-IN	HT	VOL	V_s	$e = V/V_s - 1$	$n = e/1+e$	PERM GAGE	ΔQ-cc	K-$1/sec \times 10^{4}$
1145	105		8-20	.1620	.8380	4.1137	2.3419	.7565	.4306	5.72	.28	1.82
1200	120		20	.1620	.8380	4.1137		.7565	.4306	6.77	.27	1.76
1215	135		21	.1621	.8377	4.1132		.7563	.4306	6.27	.28	1.82
1230	150		22	.1622	.8376	4.1127	$\frac{1}{V_s}$ 4270	.7561	.4305	1.55	.28	1.82
1245	165		22	.1622	.8376	4.1127		.7561	.4305	6.83	.28	1.82
1320	200		23	.1623	.8372	4.1122		.7559	.4304	7.48	.65	1.81
1350	230		25	.1625	.8375	4.1112		.7554	.4303	8.03	.55	1.79
1400	240		25	.1625	.8375	4.1114		.7554	.4303	8.22	.19	1.8
	255		2.6	.1626	.8374	4.1107		.7552	[illegible]	[illegible]	.18	1.81
	270		27	.1627	.83[illegible]	4.1103		.7550	.4301	8.7[illegible]	.16	1.79
	285		2.7	.1627	.83[illegible]	4.1103		.7550	.4301	9.02	.26	1.67
1500	300		27	.1627	.8373	4.1103		.7556	.4301	.41	.25	1.62
	315		28	.1628	.8372	4.1098		.7548	.4301	.56	.26	1.61
	330		28	.1628	.8372	4.1098		.7548	.4301	.81	.25	1.12
	345		28	.1628	.8372	4.1098		.7548	.4301	1.08	.27	1.7
1600	360	5.00	28	.1628	.8372	4.1098		.7548	.4301	1.33	.25	1.62
0900			8-43	.1643	.8357	4.1004		[illegible]	.4298			1.78
0900	0	5.00	8-43	.1643	.8357	4.1004		[illegible]	.4298	[illegible]		1.78
	5		.48	.1648	.8352	4.0977		.7530	.4297	2.23		
	10		4.9	.1649	.8351	4.0995		[illegible]	.4287	2.23		
	15		5.0	.1650	.8350	4.0990		[illegible]	.4286	2.23		
	20		5.1	.1651	.8349	4.0985		[illegible]	.4285	2.23		
	30		5.1	.1651	.8349	4.098		[illegible]	.4283	2.23		
	40		5.2	.1652	.8348	4.0980		.7492	[illegible]	2.24		
	50		5.2	.1652	.8348	4.0980		.7492	[illegible]	2.24		
	[illegible]		5.2	.1652	.8348	4.[illegible]		.7490	.4285	2.2[illegible]		
	1½ Mn		5.3	.1653	.8347	4.0986		.7490	.4284	2.25	.01	
	2		5.4	.1654	.8346	4.0975		[illegible]	.4283	2.26	.01	
	[illegible]		5.5	.1655	.8345	4.0910		[illegible]	.4283	2.27	[illegible]	
	4		5.5	.1655	.8345	4.09[illegible]5		[illegible]	.428[illegible]	2.24	[illegible]	
	5		5.6	.1656	.8344	4.0961		.7481	[illegible]	2.31	.04	1.75
	10		5.7	.1657	.8343	4.09[illegible]		.7477	[illegible]	2.[illegible]	.09	1.64
	20		6.0	.1660	.8340	4.0941		.7471	[illegible]	2.37	.17	1.[illegible]
	30		6.2	.1662	.8338	4.0931		.7471	[illegible]	2.76	.19	1.[illegible]
	45		6.4	.1664	.8336	4.0921		.7412	.4276	3.02	.2[illegible]	[illegible]
1000	60		6.5	.1665	.8335	4.0916		.7470	.427[illegible]	3.26	[illegible]	[illegible]
	75		6.6	.1666	.8334	4.0911		.7468	.4275	3.54	[illegible]	1.[illegible]
	90		6.7	.1667	.8333	4.0906		.7466	.4274	3.85	[illegible]	[illegible]
	105		6.8	.1668	.8332	4.0896		.7462	.4273	4.06	.21	[illegible]
1100	120		6.9	.1669	.8331	4.0896		.7462	.4273	4.32	[illegible]	1.[illegible]
	135		7.0	.1670	.8330	4.0891		.7460	.4272	4.8	[illegible]	[illegible]
	150		7.0	.1670	.8330	4.0891		.7460	.4272	4.[illegible]	[illegible]	[illegible]
1205	165		7.1	.1671	.8329	4.0887		.7458	.4271	5.01	.77	1.74
	180		7.1	.1671	.8329	[illegible]		.7458	.4271	5.41	.44	2.13
	195		7.1	.1671	.8329	[illegible]		.7458	.4271	[illegible]12	.17	1.64
	210		7.2	.1672	.8328	[illegible]		.7456	.4271	[illegible]	.2[illegible]	1.6[illegible]
	225		7.3	.1673	.8327	4.0877		.7454	.4270	6.1[illegible]	.2[illegible]	1.[illegible]
1300	240		7.3	.1673	.8327	4.0877		.7454	.42[illegible]	[illegible]	.26	[illegible]
	255		7.3	.1673	.8327	4.0877		.7454	.4270	[illegible]	.26	1.[illegible]8
	270		7.4	.1674	.8326	4.0872		.7452	.42[illegible]	[illegible]	.28	1.81
	285		7.4	.1674	.8326	4.0872		.7452	.4269	7.19	.25	1.61
1400	300		7.5	.1675	.8325	4.[illegible]		.7450	.4269	[illegible]	.26	1.65
	315		7.5	.1675	.8325	[illegible]		.7450	.4269	7.70	.2[illegible]	1.01
	330		7.5	.1675	.8325	[illegible]		.7450	.4269	7.94	.24	1.54
1445	345		7.5	.1675	.8325	[illegible]		.7450	.4269	8.22	.28	1.81
1515	375		7.6	.1676	.8324	4.0867		.7448	.4269	8.70	.54	1.74
1545	405		7.7	.1677	.8323	4.0862		.7447	.4268	9.24	.48	1.[illegible]4
1600	420		7.7	.1677	.8323	4.0862		.7447	.4268	9.50	.26	1.62
	435		7.7	.1677	.8323	4.0862		.7447	.4269	9.75	.25	1.61
	450		7.8	.1678	.8322	4.0857		.7443	.4267	.25	.25	1.61
	465		7.8	.1678	.8322	4.0857		.7443	.4267	.50	.23	1.49
1700	480	5.50	7.8	.1678	.8322	4.0857		.7443	[illegible]	.72	.24	1.54

TEST No 4

TIME	Δt	PRESSURE	DIAL	DIAL·IN	HT	VOL	V_s	$e = V/V_s - 1$	$n = e/1+e$	PERM. GAGE	ΔQ·cc	K·1/sec ×10^{-6}	8
0930	0 sec	5.50	8-10.1	.1701	.8294	4.0734	2.3419	.7395	.4251	0.22			
	5		10.3	.1703	.8297	4.0729		.7391	.4241				
	10		10.3	.1703	.8297	4.0729		.7391	.4249				
	15		10.3	.1703	.8297	4.0729	$\frac{1}{V_s}$ = .4270	.7391	.4249				
	20		10.3	.1703	.8297	4.0729		.7391	.4249				
	30		10.3	.1703	.8297	4.0727		.7391	.4249				
	40		10.4	.1704	.8296	4.0725		.7384	.4249				
	50		10.4	.1704	.8296	4.0725		.7389	.4249				
	60		10.4	.1704	.8296	4.0725		.7369	.4247	23	.01		
	1½ MIN		10.4	.1704	.8296	4.0725		.7381	.4247	24	.01		
	2		10.5	.1705	.8295	4.0720		.7387	.4247	25	.01		
	3		10.6	.1706	.8294	4.0715		.7385	.4247	26	.01		
	4		10.6	.1706	.8294	4.0710		.7383	.4247	27	.01		
	5		10.7	.1707	.8293	4.0710		.7383	.4247	2[illegible]	.01		
	10		10.8	.1708	.8292	4.0705		.7381	.4246	.36	.08	1.4	
	20		11.0	.1710	.8290	4.0695		.7376	.4244	.[illegible]2	.16	1.54	
	30		11.1	.1711	.8287	4.0690		.7374	.4244	.67	.15	1.45	
	45		11.2	.1712	.8289	4.0685		.7372	.4243	.72	.25	1.6[illegible]	
1030	60		11.3	.1713	.8287	4.0680		.7370	.4242	1.16	.24	1.54	
	75		11.4	.1714	.8286	4.0676		.7368	.4242	1.37	.21	1.35	
	90		11.5	.1715	.8285	4.067[illegible]		.736[illegible]	.4241	1.6[illegible]	.23	1.48	
	105		11.6	.1716	.8284	4.0666		.7364	.424[illegible]	1.83	.23	1.48	
1130	120		11.6	.1716	.8284	4.0666		.73[illegible]	.4240	2.0[illegible]	.22	1.41	
	135		11.7	.1717	.8283	4.0661		.7362	.4240	2.27	.22	1.41	
	150		11.7	.1717	.8283	4.0661		.73[illegible]	.4240	2.49	.22	1.41	
	165		11.8	.1718	.8282	4.0656		.73[illegible]	.4239	2.72	.23	1.48	
1230	180		11.8	.1718	.8282	4.0656		.73[illegible]	.4239	2.93	.21	1.34	
	195		11.9	.1719	.8281	4.0651		.7357	.4238	3.[illegible]	.22	1.41	
1330	240		12.0	.1720	.8280	4.0646		.7355	.4231	3.83	.68	1.45	
	255		12.1	.1721	.8279	4.0641		.735[illegible]	.4237	4.05	.22	1.41	
	270		12.1	.1721	.8279	4.0641		.735[illegible]	.4237	4.26	.21	1.41	
1415	285		12.2	.1722	.8278	4.0630		.7351	.423[illegible]	4.47	.23	1.34	
1445	315		12.2	.1722	.8278	4.0636		.7351	.4236	4.95	.46	1.48	
1515	345		12.2	.1722	.8278	4.0636		.7351	.4236	5.40	.45	1.44	
1545	375		12.3	.1723	.8277	4.063[illegible]		.7341	.4235	5.86	.46	1.44	
1630	420	6.00	12.3	.1723	.8277	4.0631		.7341	.4235	6.55	.67	1.48	
1420	0	6.00	8-13.8	.1738	.8262	4.0558		.7315	.4224	2.0			
	5 sec		14.1	.1741	.8259	4.0543		.7311	.4223	2.0			
	10		14.1	.1741	.8259	4.0543		.7311	.4223	2.0			
	15		14.2	.1742	.8258	4.0538		.7309	.4222	2.0			
	20		14.2	.1742	.8258	4.0538		.7309	.4222	2.0			
	30		14.2	.1742	.8258	4.0538		.7309	.4222	2.0			
	40		14.2	.1742	.82[illegible]8	4.0538		.73[illegible]	.4222	2.[illegible]			
	50		14.2	.1742	.8258	4.0538		.7309	.4222	2.01	.01		
	60		14.[illegible]	.1743	.8257	4.0533		.7307	.4221	2.01	.08		
	1½ MIN		14.3	.1743	.8257	4.0528		.7307	.4221	2.02	.01		
	2		14.4	.1744	.8256	4.0528		.7305	.4221	2.02	[illegible]		
	3		14.4	.1744	.8256	4.0528		.7305	.4221	2.03	.01		
	4		14.4	.1744	.8256	4.0528		.7305	.4221	2.04	.01		
	5		14.5	.1745	.8255	4.0523		.7303	.4220	2.05	.01		
	10		14.6	.1746	.8254	4.0518		.7301	.4219	2.14	.09	1.73	
	20		14.8	.1748	.8252	4.0507		.7296	.4218	2.28	.14	1.34	
1450	30		15.0	.1750	.8250	4.0499		.7292	.4216	2.43	.15	1.4[illegible]	
	45		15.1	.1751	.8249	4.0494		.7290	.4216	2.64	.21	1.[illegible]	
1520	60		15.2	.1752	.8248	4.0489		.7288	.4215	2.86	.22	1.41	

TEST No 4 9

TIME	Δt	Pressure	DIAL	DIAL-IN	HT	VOL	Vs	$e = \frac{1}{V_s} - 1$	$n = e/1+e$	PERM. GAGE	ΔQ-cc	K-1/sec·10^{-6}
1435	75		8-15.3	.1753	.8241	4.0484	2.3419	.7286	.4214	3.0[illegible]	.22	1.41
1450	90		15.4	.1754	.8246	4.0479		.7284	.4214	[illegible]	.22	1.41
	105		15.5	.1755	.824[illegible]	4.0474		.7287	.4213	3.12	.22	1.41
1820	120		15.6	.1756	.8244	4.0469	$\frac{1}{V_s} = .4270$	.7280	.4212	3.75	.22	1.41
	135		15.6	.1756	.8244	4.0467		.7280	.4212	3.97	.22	1.41
	150		15.7	.1757	.8243	4.0461		.7278	.4212	4.17	.22	1.41
	195		15.9	.1759	.824[illegible]	4.0455		.7274	.4210	4.87	.68	1.45
	225		16.0	.1760	.8240	4.0450		.7272	.4210	5.32	[illegible]	1.44
1920	300		16.2	.1762	.8238	4.0440		.7267	.4208	[illegible]	.23	1.47
	315		16.3	.1763	.8237	4.0435		.7265	.4207	6.68	.23	1.47
	330		16.3	.1763	.8237	4.0435		.7265	.4207	6.92	.32	1.45
	345		16.3	.1763	.8237	4.0435		.7265	.4207	7.15	.23	[illegible]
2020	360		16.3	.1763	.8237	4.0435		.7265	.4207	7.37	.22	[illegible]
	375		16.4	.1764	.8236	4.0430		.7265	.4207	7.60	.23	[illegible]
	390		16.4	.1764	.8236	4.04[illegible]		.7263	.4207	7.81	.21	1.34
	405		16.4	.1764	.823[illegible]	4.042[illegible]		.7263	.4207	[illegible]	.21	1.53
2120	420	6.50	16.4	.1764	.8236	[illegible]		.7263	.4207	8.26	.21	1.34
0915	0	6.50	8-17.3	.1771	.8227	4.03[illegible]		.7244	.4200	1.5[illegible]		
	5 sec		17.5	.1775	.822[illegible]	4.0376		.7240	.4194	1.7[illegible]		
	10		17.6	.1776	.8224	4.037[illegible]		.7238	.419[illegible]	1.81		
	20		17.6	.1776	.8224	4.037[illegible]		.7238	.419[illegible]	1.9[illegible]		
	30		17.6	.1776	.8224	4.037[illegible]		.7238	[illegible]	1.64		
	40		17.6	.1776	.8224	4.037[illegible]		.7233	.4198	1.70	.01	
	50		17.6	.1776	.8224	4.037[illegible]		.72[illegible]9	.419[illegible]	1.7[illegible]	[illegible]	
	60		17.6	.1776	.8224	4.0371		.7278	.4198	1.79	.00	
	1½ MIN		17.7	.1777	.8223	4.036[illegible]		.7236	.4198	1.8[illegible]	.01	
	2		17.7	.1777	.8223	4.0366		.7236	[illegible]	1.92	.01	
	3		17.7	.1777	.82[illegible]	4.0366		.7236	.4198	1.9[illegible]	.01	
	4		17.8	.178	.8222	4.0361		.723[illegible]	.4197	1.9[illegible]	.01	
	5		17.8	.178	.822[illegible]	4.0361		.7234	.4197	[illegible]	.01	
	10		17.9	.1779	.8221	4.0356		.7232	.419[illegible]	2.02	.07	1.34
	20		18.1	.178[illegible]	.8219	4.0347		.7228	.4195	2.16	.14	1.34
	30		18.2	.178[illegible]	.8218	4.0342		.7226	.4194	[illegible]	.14	1.34
	45		18.3	.1783	.8217	4.0337		.7223	.41[illegible]	2.50	.10	1.27
1015	60		18.4	.1784	.8[illegible]	4.0332		.7221	[illegible]	2.71	.21	1.33
	75		18.4	.1784	.8216	4.0332		.7221	[illegible]	2.92	.21	1.32
	90											
1130	105		18.6	.1786	.8214	4.0322		.7217	[illegible]	3.34	.42	1.33
	135		18.7	.1787	.8213	4.0317		.7215	.4191	3.74	.40	1.27
	150		18.8	.1788	.8212	4.0312		.7213	.419[illegible]	3.9[illegible]	.21	1.33
	165		18.9	.1789	.8[illegible]	4.0307		.7211	.41[illegible]9	4.15	.20	1.27
1215	180		19.0	.1790	.8210	4.0302		.7208	.4189	4.35	.20	1.27
	195		19.0	.1790	.8210	4.0302		.7208	.418[illegible]	4.56	.21	1.27
	210		19.0	.1790	.8210	4.0302		.7208	.4188	4.77	.21	[illegible]
	225		19.0	.1790	.8210	4.0302		.7208	.418[illegible]	4.97	.20	1.27
1315	240		19.1	.1791	.820[illegible]	4.0297		.72[illegible]	.4188	4.17	.20	1.27
	255		19.1	.1791	.820[illegible]	4.0297		.720[illegible]	[illegible]	5.38	.21	1.27
	270		19.2	.1792	.820[illegible]	4.0293		.720[illegible]	.4187	5.58	.20	1.27
	285		19.2	.1792	.820[illegible]	4.0293		.720[illegible]	.4187	5.80	.22	1.40
1415	300											
	315		19.3	.1793	.82[illegible]7	4.0288		.7202	[illegible]	6.21	.41	1.30
	330		19.3	.1793	.82[illegible]7	4.0288		.7202	.418[illegible]	6.41	.20	1.27
1515	360		19.3	.1793	.82[illegible]	4.0288		.7202	[illegible]	[illegible]	.20	1.27
1530	315	7.00	19.4	.1794	[illegible]	4.0283		.7200	.418[illegible]	[illegible]	.2[illegible]	1.27

TEST NO 10

TIME	Δt	PRESSURE	DIAL	DIAL-IN	HT	VOL	V_s	$e = V/V_s - 1$	$n = e/(1+e)$	PERM GAGE	ΔQ - cc	$K \cdot /sec \times 10^6$
0900	0 sec	9-07	.1807	7.00	.8113	4.0219	2.3419	1.7175	.4117	0.79		
	5	176	.1976		.8024	3.9367		1.6819	.4054			
	10	28	.2028		.7972	3.9134		1.6710	.41[illegible]	PERMANENT DRIVE [illegible]		
	20	7.0	.2070		.7930	3.8128	$\frac{1}{V_s} = .4270$	1.6622	.3987			
	30	12.0	.2120		.7880	3.8682		1.6517	.39[illegible]			
	40	13.5	.2135		.7865	3.8609		1.6486	.3934			
	50	14.1	.2141		.7859	3.8579		1.6470	.39[illegible]			
	60	14.5	.2145		.7855	3.8560		1.6465	.3926			
	1½ MIN	15.8	.2158		.7842	3.8496		1.6437	.3916			
	2	15.9	.2159		.7841	3.8491		1.6435	.3915			
	3	16.0	.2160		.7840	3.8486		1.6423	.39[illegible]			
	4	16.3	.2163		.7837	3.8468		1.6425	[illegible]			
	5	16.6	.2166		.7834	3.8457		1.6421	.3910			
	10	17.1	.217[illegible]		.7829	3.8432		1.6410	[illegible]			
	20	17.6	.2176		.7824	3.8408		1.6400	[illegible]	.72		
	30	17.9	.2179		.7821	3.8393		1.6393	[illegible]	.85	.11	[illegible]
	40	18.2	.2182		.7818	3.8378		1.6387	[illegible]	[illegible]	[illegible]	1.82
	50	18.3	.2183		.7817	3.8373		1.63[illegible]	.3896	[illegible]3	.10	1.62
1000	60	18.4	.2184		.7816	3.8368		1.6383	.3896	[illegible]	.12	[illegible]
	70	18.6	.2186		.7814	3.835[illegible]		1.6378	.3894	1.44	[illegible]	[illegible]
	105	18.7	.2187		.7813	3.83[illegible]		1.6377	[illegible]	1.58	[illegible]	[illegible]
1100	120	18.8	.2188		.7812	3.8341		1.6375	.3893	1.74	[illegible]	[illegible]
	155	18.9	.2189		.7811	3.8344		1.6372	[illegible]	[illegible]	.21	[illegible]
1200	150	19.0	.2190		.7810	3.8339		1.6370	[illegible]	[illegible]	[illegible]	[illegible]7
	195	19.1	.2191		.7809	3.83[illegible]		1.6368	[illegible]	2.47	[illegible]	[illegible]
	210	19.2	.2192		[illegible]	3.8324		1.6366	[illegible]	2.60	.13	[illegible]
	225	19.2	.2192		.7808	3.8324		1.6366	[illegible]	[illegible]	[illegible]	[illegible]
1300	240	19.2	.2192		.7808	3.[illegible]24		1.6366	[illegible]	2.91	[illegible]	[illegible]
	255	19.3	.2193		[illegible]	3.832[illegible]		1.6364	[illegible]	[illegible]	[illegible]	[illegible]
	270	19.3	.2193		[illegible]	3.832[illegible]		1.6364	[illegible]	3.10	[illegible]	[illegible]
	285	19.3	[illegible]		.7807	3.8324		1.6364	[illegible]	[illegible]	[illegible]	[illegible]
1400	300	19.4	.2194		.7806	3.8319		1.6362	[illegible]	[illegible]	[illegible]	[illegible]
	315	19.4	.2194		[illegible]	3.83[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	330	19.5	.2195		[illegible]	[illegible]		[illegible]	.3887	[illegible]	.14	[illegible]
	345	19.5	.2195		[illegible]	3.8311		[illegible]	.3887	3.93	[illegible]	.40
1500	360	19.[illegible]	.2195	16.00	.7805	3.8311		[illegible]	[illegible]	4.06	.13	[illegible]

TEST N 11

11

SAMPLE DATA

SPECIFIC GRAVITY	2.59
INITIAL HEIGHT of SAMPLE	1.0000 IN.
FINAL HEIGHT of SAMPLE	.7805 IN
CROSS SECTIONAL AREA	4.9087 IN^2
INITIAL MOISTURE CONTENT	41%
FINAL MOISTURE CONTENT	29%
WEIGHT of SOLIDS	97.4 grams
VOLUME of SOLIDS	2.3419 IN^3